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Gibraltar NO_2 TEN: source attribution analysis

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AEA group
329 Harwell
Didcot
Oxfordshire
OX11 0QJ

t: 0870 190 6510
f: 0870 190 6318

Author	Name	Andrew Kent Nigel Gibson John Abbott
Approved by	Name	Steve Telling
	Signature	
	Date	

Executive summary

Concentrations of NO_X and NO_2 have been measured in Gibraltar and reported to the European Commission since 2005, in accordance with European Directives[1,2,3]. The Gibraltar Air Quality Monitoring Network has recorded exceedences of the annual mean Limit Value (LV) imposed under the First Daughter Directive and subsequent EU Air Quality Directive at two monitoring sites in 2008 (Rosia Road and Witham's Road). The LVs for NO_2 are due to come into force in 2010 and many Member States (including the UK) have struggled to achieve the annual mean LV + Margin of Tolerance (MOT).

Given the exceedences measured at Rosia Road and Witham's Road in 2008, Gibraltar is compelled under the Directive to provide a Plans & Programmes report to the Commission no later than December 2010 which assess the likelihood of the zone achieving compliance by the 2010 deadline and details any measures required in order to ensure compliance. Many Member States, including the UK, are currently compiling applications for time extensions for NO_2 and have already submitted similar applications for PM_{10}. Due to anticipated exceedence of the annual NO_2 LV in years up to 2010, the Government of Gibraltar has elected to proceed with a formal application for a time extension (TEN) to the extended deadline of 2015 for this LV in lieu of a Plans & Programmes report for 2008.

The provision for formal time extension applications and associated guidance has been developed in parallel with the new EU Air Quality Directive and the mechanism for applying for a time extension has been modelled on Plans & Programmes reporting submissions that were in place in the run up to the LVs coming into force. The TEN application process provides scope to clarify and quantify the nature of the measured exceedences and to present the policy measures put in place to address them, by doing so demonstrating how the Member State intends to achieve compliance with the LVs at the end of the time extension period. To this end, this report presents modelling analysis of NO_X and NO_2 in support of a formal application by the Government of Gibraltar for a time extension (TEN) to the Limit Values (LVs) imposed under the First Daughter Directive and subsequent updated EU Air Quality Directive of 2008.

The modelling and source apportionment assessment show that NO_X contributions from the OESCO and MOD power stations and from road traffic are the most significant sources of NO_X in Gibraltar and that of these, the power station is by far the largest contributor.

The Government of Gibraltar plan to implement two significant measures to address sources of NO_X and NO_2. These are to build a new, up-to-date power station with appropriate abatement technology, located to the south of the main urban development and with a significantly higher stack than the current power stations. The existing three power stations are to be turned off in conjunction with this measure. Additional reductions in NO_X and NO_2 are expected through the Gibraltar Transport Plan and EURO standards though these have not been quantified in this assessment. The decline in NO_X resulting from these measures and assessment of expected effect on NO_2 concentrations shows that the power station measure alone would result in compliance with the NO_2 LV.

It is recommended that the Government of Gibraltar, supported by the Gibraltar Environmental Agency, pursue a formal TEN application for the annual mean NO_2 LV until the end of 2014 and that they implement the measures identified in the Air Quality Action Plan accompanying the formal TEN applications. Whether the TEN is granted or not, there is a continued necessity for the monitoring programme in order to provide mandatory reporting to the Commission. If the TEN is successful then the monitoring is required to demonstrate the ongoing success of the abatement measures implemented under the Action Plan. If the TEN is unsuccessful then due consideration should be given to additional, alternative and possibly more stringent measures in order to achieve compliance with the LV so that ongoing infraction is avoided.

[1] Directive 96/62/EC on Ambient Air Quality Assessment and Management (The Framework Directive)
[2] Directive 1999/30/EC (the first Daughter Directive)
[3] Directive 2008/50/EC (The EU Air Quality Directive)

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1 Introduction

Concentrations of NO_X and NO_2 have been measured in Gibraltar and reported to the European Commission since 2005, in accordance with European Directives[4,5,6]. The Gibraltar Air Quality Monitoring Network has recorded exceedences of the annual mean Limit Value (LV) imposed under the First Daughter Directive and subsequent EU Air Quality Directive at two monitoring sites in 2008 (Rosia Road and Witham's Road). The LVs for NO_2 (summarised in Table 1-1) are due to come into force in 2010 and many Member States (including the UK) have struggled to achieve the annual mean LV + Margin of Tolerance (MOT).

Table 1-1 Limit Values for NO_2, set down in the First Daughter Directive

Metric	Limit Value
Hourly mean LV	200 µg m^{-3} (not to be exceeded more than 18 times per calendar year)
Annual mean LV	40 µg m^{-3}

The LVs for NO_2 are due to come into force in 2010 and many Member States (including the UK) have struggled to achieve the annual mean LV + Margin of Tolerance (MOT). Exceedences and concentrations measured in Gibraltar from the inception of the monitoring network are summarised in Table 1-2 which illustrates the rise since 2005.

Table 1-2 Summarised NO_X and NO_2 concentrations in Gibraltar

Site	Pollutant	2005	2006	2007	2008
Rosia Road	NO_X	85	91	94	89
	NO_2	42	42	44	45
Witham's Road	NO_X	----	----	----	149
	NO_2	----	----	----	53
Bleak House	NO_X	34	37	40	39
	NO_2	24	24	25	26

Given the exceedences measured at Rosia Road and Witham's Road in 2008, Gibraltar is compelled under the Directive to provide a Plans & Programmes report to the Commission no later than December 2010 which assess the likelihood of the zone achieving compliance by the 2010 deadline and details any measures required in order to ensure compliance. Many Member States, including the UK, are currently compiling applications for time extensions for NO_2 and have already submitted similar applications for PM_{10}. Due to anticipated exceedence of the annual NO_2 LV in years up to 2010, the Government of Gibraltar has elected to proceed with a formal application for a time extension (TEN) to the extended deadline of 2015 for this LV in lieu of a Plans & Programmes report for 2008.

The provision for formal time extension applications and associated guidance has been developed in parallel with the new EU Air Quality Directive and the mechanism for applying for a time extension has been modelled on Plans & Programmes reporting submissions that were in place in the run up to the LVs coming into force. The TEN application process provides scope to clarify and quantify the nature of the measured exceedences and to present the policy measures put in place to address them, by doing so demonstrating how the Member State intends to achieve compliance with the LVs at the end of the time extension period. To this end, this report presents modelling analysis of NO_X and NO_2 in support of a formal application by the Government of Gibraltar for a time extension (TEN) to the Limit Values (LVs) imposed under the First Daughter Directive and subsequent updated EU Air Quality Directive of 2008.

[4] Directive 96/62/EC on Ambient Air Quality Assessment and Management (The Framework Directive)
[5] Directive 1999/30/EC (the first Daughter Directive)
[6] Directive 2008/50/EC (The EU Air Quality Directive)

The analysis presented in this document is designed to:

1. identify and quantify the most significant sources of NO_X and NO_2 in Gibraltar
2. demonstrate the effectiveness of proposed policy measures in achieving the LVs in time for the extension period being applied for.

NO_X contributions from the OESCO and MOD power stations and from road traffic are anticipated to be the most significant sources of NO_X measured in Gibraltar and the Government of Gibraltar's proposed measures to achieve compliance with the AQ Directive are concentrated on these sources. Therefore these sources are the focus of the analysis presented here.

The Government of Gibraltar are also applying for a time extension to the PM_{10} daily limit value until 2011 (the maximum time extension allowed). There is a corresponding technical report to support the PM_{10} time extension application[7]. Much of the methodology employed in this analysis has been undertaken for consistency with the PM_{10} studies.

It should be noted that Gibraltar's application for a time extension for NO_2 is based on a reference year of 2008 (for PM_{10} the reference year was 2007) as this was the first year that the NO_2 limit value plus margin of tolerance (LV+MOT) was exceeded.

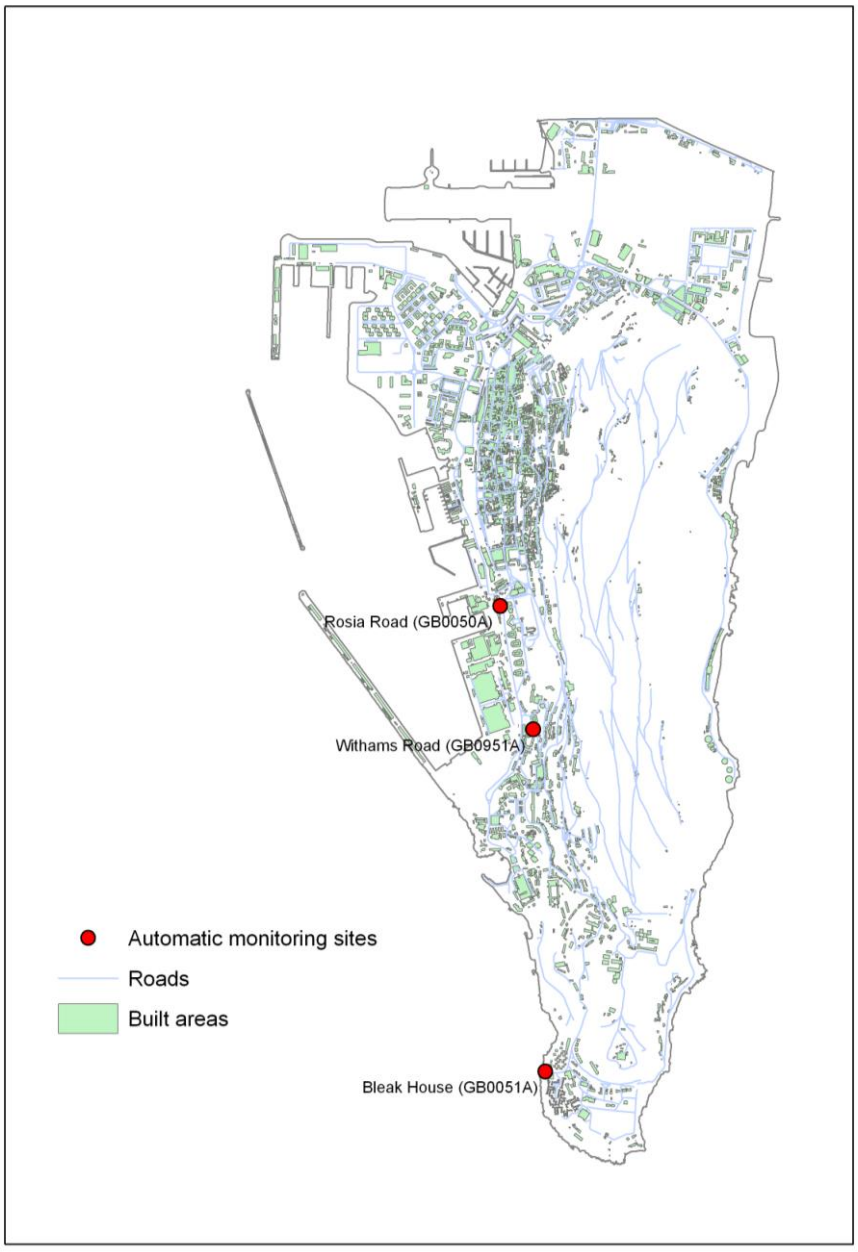
The details of the Gibraltar Air Quality monitoring network are summarised in Chapter 2 for NO_X and NO_2. This contains site information for the stations that exceeded the annual mean LV in the reference year of 2008. Chapter 3 discusses the available meteorological data used within this study and the issues regarding dispersion in Gibraltar, with particular reference to the influence of topography. This feature is further discussed in relation to the explicit power station modelling in Chapter 4. The power station modelling conducted for OESCO and MOD power stations is summarised in Chapter 4. This chapter also contains a summary of modelling undertaken for the proposed new power station that is the central measure adopted by the Government of Gibraltar to abate NO_X emissions in Gibraltar to achieve compliance with the Directive. Modelling to quantify contributions from road traffic emissions to NO_X concentrations measured in Gibraltar is summarised in Chapter 5. Chapter 6 contains a summary of the NO_X source apportionment and the justification of the approach in incorporating contributions from the power station and road traffic modelling studies. Chapter 7 represents the approach taken to relating the NO_X source apportionment to the NO_2 concentrations anticipated as a result of the mitigating measures taken by the Government of Gibraltar and demonstrates expected compliance as a result of these measures. Chapter 8 summarises this information and provides recommendations for the Gibraltar Environmental Agency and the Government of Gibraltar.

[7] Kent, A. J. (2010) Gibraltar PM_{10} TEN: source attribution analysis (report to Gibraltar Environmental Agency: AEAT/ENV/R/2845 Issue 1)

2 The Gibraltar Air Quality Monitoring Network

The Gibraltar Air Quality Network has been operational since 2005 and in 2009 consisted of 3 automatic monitoring stations, all of which measure NO_X as well as a wider suite of pollutants including PM_{10}, $PM_{2.5}$, O_3, CO, SO_2, heavy metals, VOCs and PAH. The automatic monitoring stations are identified in Figure 2-1. A summary of site details of the stations are provided in Table 2-1 including the site classification (background or roadside) and list the other pollutant species measured by automatic analysers.

Figure 2-1 Location of the Gibraltar PM_{10} automatic monitoring sites



NO_X is measured at all three monitoring stations in Gibraltar and the NO_2 annual mean LV in 2008 was exceeded at two of them: Rosia Road and Witham's Road. The Witham's Road monitoring site began operation in 2008 in response to elevated indicative NO_2 diffusion tube measurements made at

this location. As a result the site was believed to represent the maximum hotspot concentrations resulting from the power station emissions. Although this is a roadside environment, the traffic flow along side the monitor is substantially less than that reported for Rosia Road. The road runs up hill past the monitoring station but the narrowness (and associated one-way system) of the road prevents heavy duty vehicles and forces the flow of traffic in the downhill direction. As a result of these factors and despite street canyon conditions for much of the area, road traffic emissions are not expected to make a significant contribution to measured concentrations.

Table 2-1 Summary table of Gibraltar automatic monitoring sites measuring NO_X and NO_2

Site	Type	Other pollutants
Rosia Road	Roadside	• PM_{10} • $PM_{2.5}$ • CO • SO_2 • VOCs • PAH • Heavy metals
Bleak House	Background	• PM_{10} • Ozone
Witham's Road	Roadside	• None

3 Meteorological data

As demonstrated in the corresponding PM_{10} source apportionment report[8], several met data sets have been compiled by AEA to assist in the investigation of air pollution in Gibraltar. Consideration of such data is essential in determining the contributing sources to measured levels (particularly wind direction) and in determining the effectiveness of dispersion at particular locations (particularly wind speed). Three of these data sets have been derived from meteorological monitoring equipment at the air quality monitoring sites themselves (Rosia Road, Bleak House and Witham's Road). These two data sets have the advantage of corresponding directly to the air pollution concentrations measured as the met data is co-located.

A met data set has been purchased from the UK Met Office which refers to the met conditions at the Gibraltar Airport (location labelled in Figure 2-1) between 2002 and 2006. Although this data does not include 2008 (the reference year for NO_2 for the TEN application), the 5 year met history from the airport is enough to help provide a more regional context for the met conditions measured at the two monitoring stations.

3.1 QA/QC of met data

Unlike pollution data in Gibraltar (which is ratified to the same standard as the UK National Networks), there are no formal quality control procedures in place for met data measured at the Rosia Road or Bleak House monitoring stations. Data for the airport is assumed to be of high quality with appropriate checking and QA procedures since it is a commercial product of the UK Met Office.

The met data has undergone a pre-process of quality control to ensure that any idiosyncrasies are understood and explained and, where necessary, that these are corrected or removed. This has been undertaken using the Openair[9] suite of tools and consideration has been given to negative wind speeds, excessive wind speeds and unrealistic distribution of wind directions. Negative wind speeds have been removed from the data. Excessive wind speeds have been arbitrarily capped at 20 ms^{-1}.

3.2 Wind rose and polar frequency analysis

Using the Openair toolset, the available met data was interrogated using wind rose plots (

[8] Kent, A. J. (2010) Gibraltar PM_{10} TEN: source attribution analysis (report to Gibraltar Environmental Agency: AEAT/ENV/R/2845 Issue 1)
[9] Openair is an open-source air quality analysis toolset developed under a NERC grant with additional funding and support from Defra (http://www.openair-project.org/)

Figure 3-1) and polar frequency plots (Figure 3-2). Initially the met data was examined as a complete record and so

Figure 3-1 and Figure 3-2 show data over a number of years for which the measurements exist rather than examining it on an annual, monthly, daily or diurnal basis. The wind rose plots show wind direction (in degrees about the plot origin), the wind speed (divided into specific 'bins' and represented by the paddle width) and the percentage of time for each direction/wind speed bin (distance from the plot origin).

Figure 3-1 therefore shows that winds at Rosia Road are generally from the SW/SSW between 20% and 25% of the time and that wind speeds for any direction are rarely above 2 ms^{-1}. This is in contrast to measured met parameters at Bleak House and Gibraltar airport where wind speeds are generally much higher and more varied in terms of direction. The data from Witham's Road shows how the site is affected by street canyon conditions – the met variation here is very different from the data at the other sites and almost exactly opposite in terms of prevailing wind axis of the nearby Rosia Road station. The prevailing north west – south east winds here are in alignment with the direction of the street canyon. As a result, NO_X emissions from the OESCO and MOD power stations (and road traffic emissions at Rosia Road) are forced into the street canyon by prevailing winds, resulting in the high concentrations reported at the automatic monitoring station.

The interesting topography of Gibraltar is immediately apparent in these plots. Rosia Road is affected by the Rock itself providing shelter from winds from the east whereas the open sea to the south west results in winds from this direction for the majority of the time. A feature of the topography's effect on met data is a 'rotor effect' that occurs when regional winds are easterly, blowing over the Rock and then rotating over the rock and then reaching Gibraltar from the opposite direction. Wind speeds measured at Rosia Road are significantly lower than the regional trend (represented by the airport location) and this is a contributory feature of the measured exceedences at the site. The average wind speed measured at Rosia Road when the measured wind direction is from the road (easterly) is 1.4 ms^{-1}, resulting in poor dispersion of road traffic emissions in close proximity to the monitoring site.

Bleak House is situated on a cliff above the water south of the Rock and is less affected by air mass blocking by the topography. Instead there is a more prevalent easterly or westerly wind directions that result from winds being funnelled through the Straits of Gibraltar. Wind speeds are higher here due to the open aspect and the height of the station. Gibraltar airport is located to the north of the Rock and so gets strong winds from the east and west (both directions are dominated by open runway and then open sea). Witham's Road's street canyon environment is evident in the polar frequency plot as well as the wind rose plot – the most commonly occurring conditions are winds from the north west and south east, in alignment with the canyon. The strongest winds are from the northern end of the canyon near Rosia Road.

The polar frequency plots show the trends in an alternative way, binning the data by wind speed and direction and then representing the number of records in each bin using a colour scale. On these plots the wind direction remains represented by degrees about the plot origin but wind speed is now represented by the distance from the origin in ms^{-1}. From these plots it is easier to see the most commonly occurring wind directions and speeds.

3.3 Met data used for modelling

It has been noted in Section 1 that the data analysis used to support Gibraltar's application for a time extension is often based on data that is not directly associated with the reference year (2008 for NO_2) for the application. In the case of the modelling studies carried out for road traffic and power station contributions to measured NO_X, the met data used was from Gibraltar airport for 2006. The Gibraltar airport location was selected for use rather than the met data gathered from the individual monitoring sites because the met mast is situated in a wide, open unobstructed space and does not experience the same topographically related met effects caused by the Rock as the other data sets. The 2006 met data was the available data at the time of the analysis. In order to demonstrate that the met conditions measured at this location do not significantly vary between years (particularly between the year used and the reference year), the variation in wind speed and direction was plotted over successive years from 2002 onwards, as shown in

Figure 3-3. This illustrates that from 2003 onwards the met data has been very similar and so modelled concentrations for 2006 are likely to be representative of the reference year (no known emissions source changes are believed to have taken place for each of the modelled components from 2006 to 2007).

Figure 3-1 Wind rose plots for air quality monitoring stations and Gibraltar airport

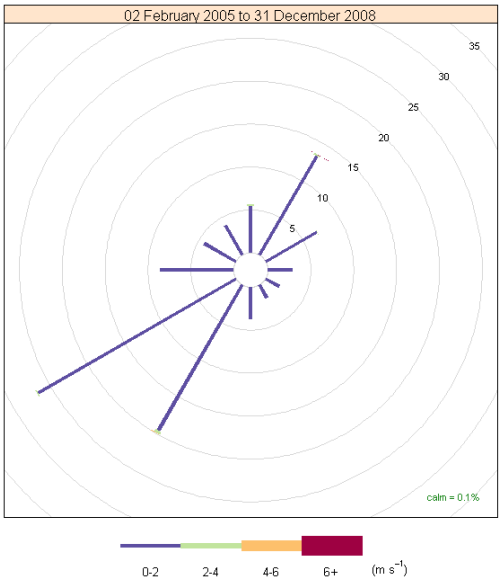
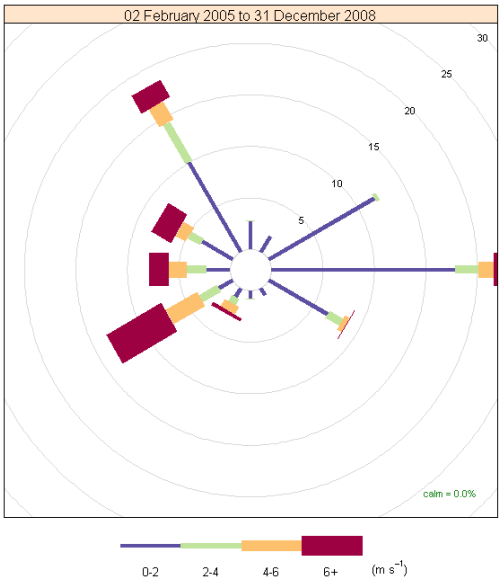
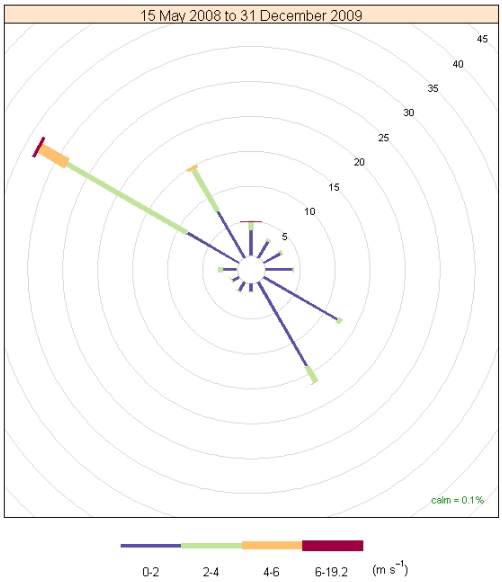
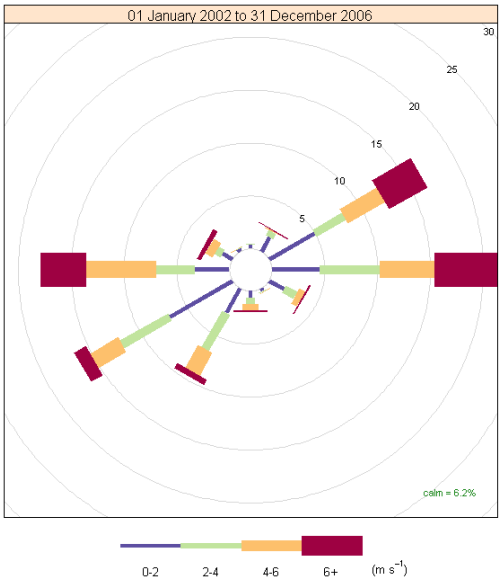
Rosia Road	Bleak House
	
Witham's Road	**Gibraltar airport**
	

Figure 3-2 Polar frequency plots for air quality monitoring stations and Gibraltar airport

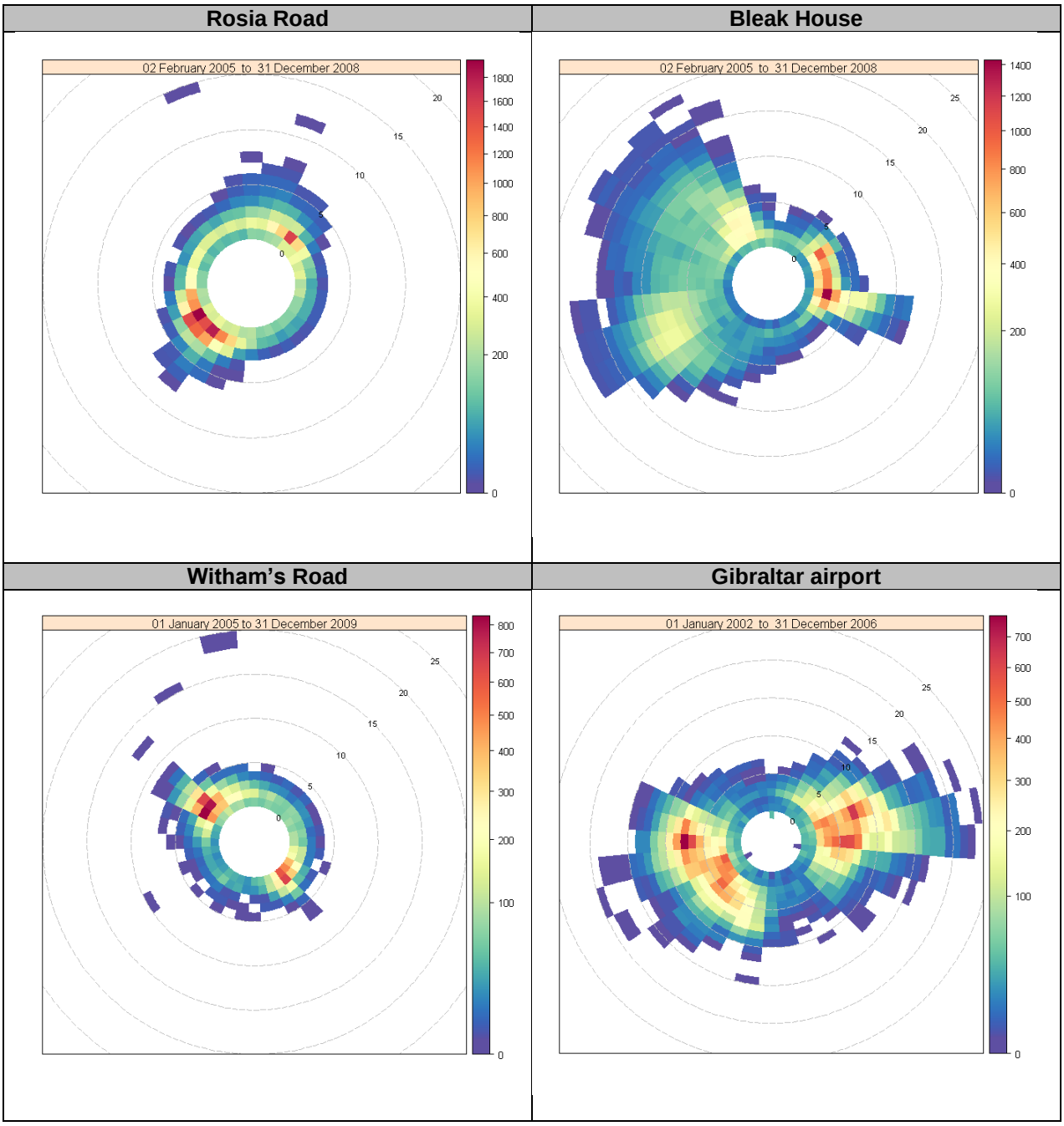
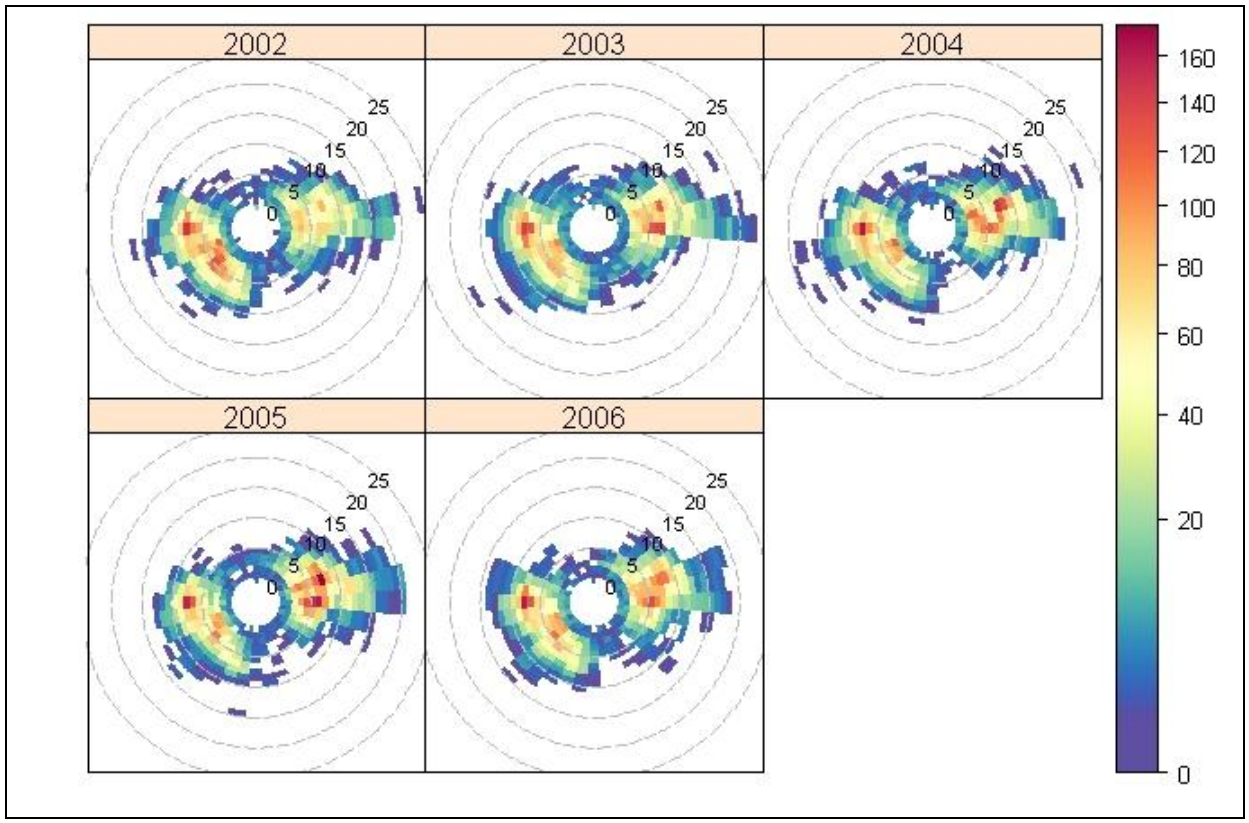


Figure 3-3 Variation in met data at Gibraltar airport 2002-2006



4 Power station contributions

4.1 Baseline concentrations (2008)

A modelling exercise undertaken by AEA for the Gibraltar Environmental Agency demonstrated that the OESCO and MOD power stations situated in close proximity to Rosia Road monitoring station made a significant contribution to measured PM_{10} concentrations[10]. Additional modelling using the same methodology was conducted for NO_X[11]. Despite the reference year of 2008 for the NO_2 TEN application, it is noted that the modelling was conducted using 2006 met data but that this is likely to be adequately representative of 2008 as demonstrated in Figure 3-3. The complete methodology and results of the modelling study are presented in the referenced report but are summarised here.

Note that the dispersion model applied in the study (ADMS) was not capable of simultaneously representing the dispersion associated with the extreme topographical nature of the Rock of Gibraltar and the dispersion associated with buildings. As a result, separate model runs were conducted one at a time to account for each and both sets of results were presented – these are presented in Table 4-1.

Table 4-1 Summary results for 2006 dispersion modelling of Gibraltar power station contributions to NO_X annual mean concentrations (µg m^{-3}) (taken from Abbott report, 2007)

Receptor site	Complex Terrain (2006)	Buildings (2006)
Rosia Rd - GIB1	21	16
Jumper's – Rosia Rd	22	153
Red Sands Rd	32	153
South Barracks Rd	7	7
Picton House - Rosia Prom	33	51
Upper Entrance	21	38
Witham's Rd	15	70
Almeda Gardens - Theatre	63	100
Almead Gardens - Main Access	40	74
Rock Hotel - Europa Rd	21	57
Gardiner's Rd	36	29
Governors Meadow - Rosia Prom	44	134
Dockyard Rd	52	108
Woodford Cottages - Europa Rd	5	3

There was a wide range in model estimates between the two sets of model results. It was decided for the purposes of this assessment that representing the buildings within the model was most appropriate for the Witham's Road monitoring station in order to account for the street canyon environment. Without representing the buildings here, the model estimates are unrealistically low compared with the exceptionally high measured concentrations at the site. The difference between the two model runs for Rosia Road was much less significant. Therefore it was decided that the buildings model run was appropriate here also – this would give a lower contribution from the power station than incorporating the terrain effects but this smaller discrepancy between the model runs would be lower than for Witham's Road and ensured that the results between the two monitoring sites would remains consistent.

[10] Abbott, J (2009) Dispersion modelling of MOD and OESCO power station PM_{10} discharges (AEA Report to Gibraltar Environmental Agency: AEA/ED43072/R2835 Issue 1)
[11] Abbott, J (2007) Dispersion modelling of MOD and OESCO power station discharges (AEA Report to Gibraltar Environmental Agency: AEA/ED48335/R2455 Issue 1)

4.2 Concentrations associated with proposed new power station

The modelling provided by AEA for 2006 is adequate to represent estimated contributions for the reference year (2008) from the power station. Additional modelling work was undertaken by Air Quality Consultants (AQC) on behalf of Environmental Gain (ENGAIN) and included in the Environmental Statement[12] for the proposed power station at Lathbury Barracks.

AQC modelled annual mean NO_X contributions from the new power station at Lathbury Barracks were 0.1 µg m^{-3} at both Rosia Road and Witham's Road (ENGAIN Environmental Statement - technical reports, Volume 2: Air Quality,Table AQ6-1, p.44). This modelling was performed for the year 2011 and helped inform the formal PM_{10} TEN application by demonstrating anticipated concentrations from the new power station in the year at the end of a time extension period for PM_{10}. Other pollutants, including NO_X were also modelled along with PM_{10} for 2011. Although this year is not specifically relevant to NO_2 compliance at the end of an NO_2 extension period, the modelled concentrations can be considered representative of 2015 due to the lack of variation in operational parameters at the new power station. The modelling was based on a 40m stack – this is the specification selected by the Government of Gibraltar, with an option to upgrade to a 50m stack at a later date if required. It was decided that for the purpose of this assessment and for the source apportionment, the maximum modelled concentration would be used for a conservative estimate of the impact of the new power station - this was 2.5 µg m^{-3} (*pers comm.* Steve Moorcroft, AQC[13]).

This represents a significant decline in contribution resulting from new power station technology and standards, a location further from the main centre of population and a higher stack. Central to applicability of this analysis in supporting the TEN application is the proposed decommissioning of the existing three power stations (ENGAIN environmental statement - technical reports, Volume 2: Air Quality, p.42).

Associated with the operation of the new power station at Lathbury Barracks is the closure of the existing power stations: OESCO, MOD and Waterport. The Waterport power station is located close to frontier and not explicitly modelled in this assessment so it is anticipated that there will be an additional NO_X benefit associated with this measure that has not been explicitly quantified in this assessment. Though the capability of the existing power stations will be retained while the new power station comes online and is tested, the decommissioning of existing power stations is planned to occur in a manner that will not result in both the new power station and existing power stations running concurrently.

[12] Proposed new power station, Lathbury Barracks, Gibraltar: Environmental Statement (Volume 2: technical reports; Chapter 1 (Air Quality) and appendices AQ1-AQ5
[13] *pers comm*. Steve Moorcroft: email of 12/05/2010 (Air Quality Consultants, 12 Airedale Road, London. SW12 8SF)

5 Road traffic contribution

5.1 Road traffic dispersion modelling

Dispersion modelling (AEA's LADSUrban tool) has been used to predict the contribution from road traffic to annual mean ground level NO_X concentrations. This alternative approach to apportioning NO_X to road traffic sources has been undertaken in addition to calculating the roadside increment.

5.1.1 Exhaust emissions contribution

AEA's LADSUrban modelling tool calculates atmospheric dispersion using a 10m x 10m x 3m volume-source kernel derived from the dispersion model ADMS4 to represent elements of the road. The volume source depth takes account of the initial mixing caused by the turbulence induced by the vehicles. The model used hourly sequential wind speed and direction data for 2006 from the Rosia Road monitoring station and cloud cover data from Gibraltar airport to derive the volume source kernel. The model application used a surface roughness of 1m to represent the urban conditions and limited the Monin-Obukhov length to 30m or greater to take account of the urban heat island effect. The model calculated the contribution from road traffic on a rectangular grid of receptors paced at 10m intervals within 150m of the modelled roads and more widely spaced receptors elsewhere. The model also calculated the contribution from the road traffic to concentrations at the Rosia Road monitoring site.

The model was used to represent the dispersion of emissions from road traffic on the roads close to the monitoring site. The roads included sections of Rosia Road, Boyd Street, Trafalgar Road, Ragged Staff Road and Queensway. Road traffic flows were taken from the official 2-way counts for Rosia Road taken by the Highways Agency in Gibraltar for the periods:

- 30/10/2006-12/11/2006 and 04/06/2007-17/06/2007 (Northbound)
- 30/10/2006-12/11/2006 and 04/06/2007-24/06/2007 (Southbound)

This data is based on the ARX classification scheme (a modified version of AustRoads94), which contains 12 specific classes of vehicle ranging from very small/light (Class 1) to very heavy (Class 12). Unfortunately the classification is principally based on vehicle length and number of axles rather than vehicle or engine type which is more useful for emissions and air quality analysis. For example, in Class 1 it includes bicycles which are non-polluting and motorcycles which are polluting (particularly the 2-stroke variety which are very polluting). Class 2 includes vehicles ranging from small cars to large utility vehicles and light vans which may vary substantially in terms of emissions. Class 3 is a classification for vehicles towing (boats, caravans and trailers) and the vehicle type and pollution associated with it could be any type of vehicle. Classes 4 through 12 all cover heavier vehicles such as trucks or buses, non-articulated or articulated with different numbers of axles which aren't likely to vary significantly in terms of contribution to air quality. Therefore the lower classes are not disaggregated enough to provide very useful emissions information and the higher classes (4-12) are split up to an unnecessary extent for emissions analysis. It was assumed that the majority of towing vehicles would be in Class 2 so cars and vans were represented by both classes together. Class 1 was split into smaller bikes (mopeds and scooters with 2-stroke engines) and larger bikes (motorcycles) using a percentage split derived from the ratio of motorcycles to mopeds/scooters from the Environmental Agency traffic counts. It was assumed that none of the Class 1 vehicles were bicycles which are very rare in Gibraltar compared with mopeds and scooters.

Resultant road traffic counts by vehicle class for Rosia Road are presented in Table 5-1. The road traffic counts were assumed to be half the stated value on 1-way sections of the road at the Rosia Road/Ragged Staff Road junction.

A similar modelling approach has been used to calculate the contribution from the road traffic to concentrations at the Witham's Road monitoring site. In the case of Witham's Road approximately half the road has two way traffic flow, the remainder being one way. The road layout is such that HGVs are unable to pass down the road. The predicted traffic flows assigned to Witham's Road are shown in Table 5-1.

Table 5-1 Traffic count used in this assessment (automatic traffic counts – 11 day period)

	Vehicle class			
	HGVs	Cars/ Vans	M/cycles	Mopeds/ Scooters
Rosia Road	5621	74117	5339	20327
Witham's Road	0	7412	534	2033

Typical emission factors for NO_X were compiled for different vehicle classes at different speeds in Gibraltar. These are derived from the latest speed related emissions factors available from the DfT[14] and are summarised in Table 5-2. The emission factors for 20 mph were used to estimate the emissions from vehicle exhausts on Rosia Road and Witham's Road.

Table 5-2 Typical exhaust emission factors (g/km) for NO_X by vehicle class and speed for Gibraltar

Speed	Vehicle class			
	HGVs*	Cars/Vans**	M/cycles***	Mopeds/ Scooters ‡
20	7.95	0.69	0.22	0.02
25	7.16	0.61	0.22	0.02
30	6.57	0.57	0.23	0.02
35	6.12	0.54	0.25	0.02
40	5.79	0.53	0.26	0.02

* HGVs assumed to be EURO II HGVs
** Cars/vans assumed to be EURO 2 vehicles, petrol engines with 1.4-2.0 litre; diesel engines >2.0 litre; vans treated as N1 Class III; with split of 75% cars and 25% vans. 80% of cars treated as petrol and 20% diesel.
*** Motorcycles assumed to be 4-stroke 150-250cc engines
‡ Mopeds/scooters assumed to be 2-stroke <150cc engines

Figure 5-1 shows the predicted contribution from road traffic to annual mean ground level NO_X concentrations at Rosia Road and Figure 5-2 shows the modelled contribution at Witham's Road. The predicted NO_X contribution is 34.9 $\mu g\ m^{-3}$ at the Rosia Road monitoring site and 1.5 $\mu g\ m^{-3}$ at Witham's Road.

It is concluded that the dispersion modelling confirms that road traffic emissions make a substantial contribution to the measured concentrations at the Rosia Road monitoring site. Dispersion modelling demonstrates that the road traffic emissions make a small contribution to the measured concentration at the Witham's Road site.

[14] http://www.dft.gov.uk/pgr/roads/environment/emissions/

Figure 5-1 Modelled NO_X contribution from road traffic near the Rosia Road monitoring site

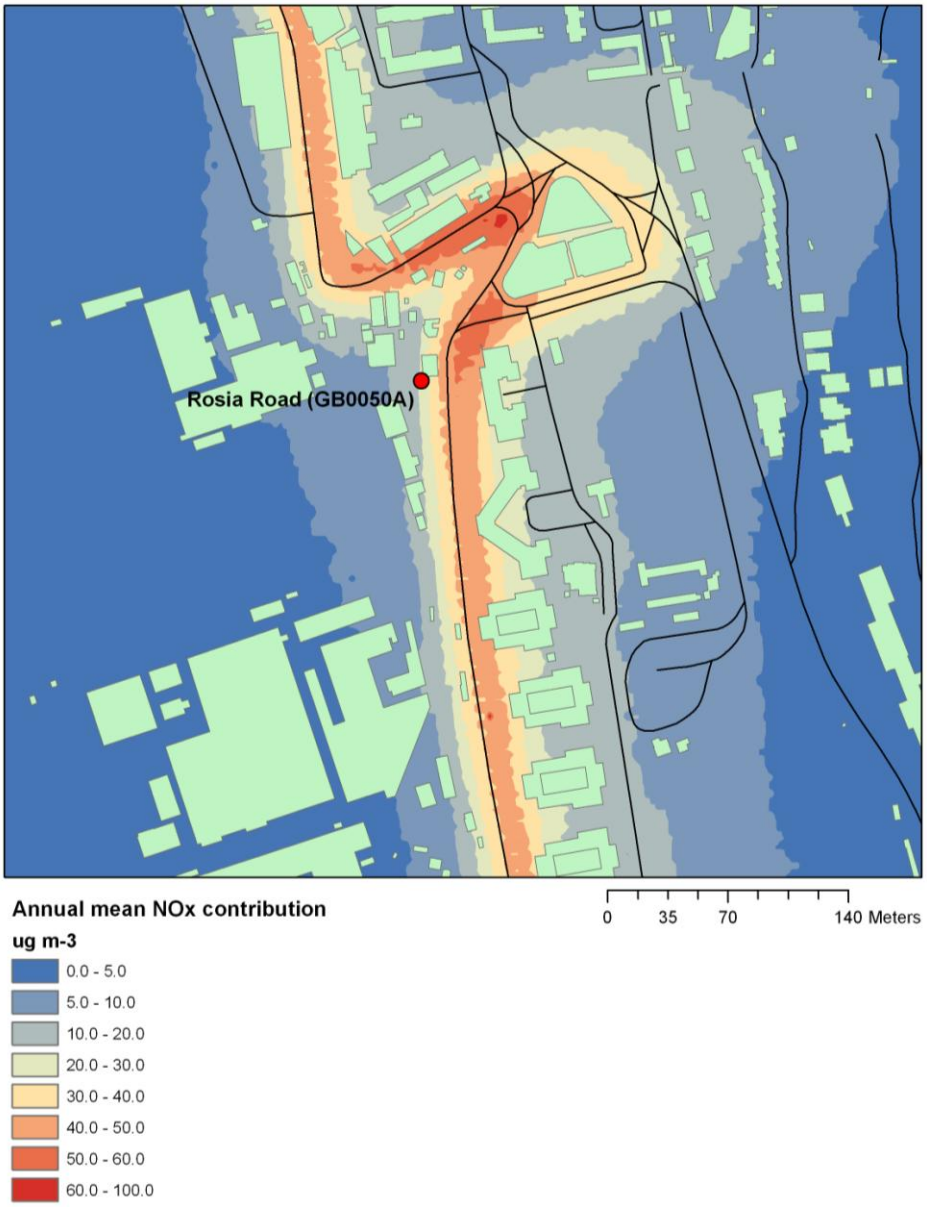
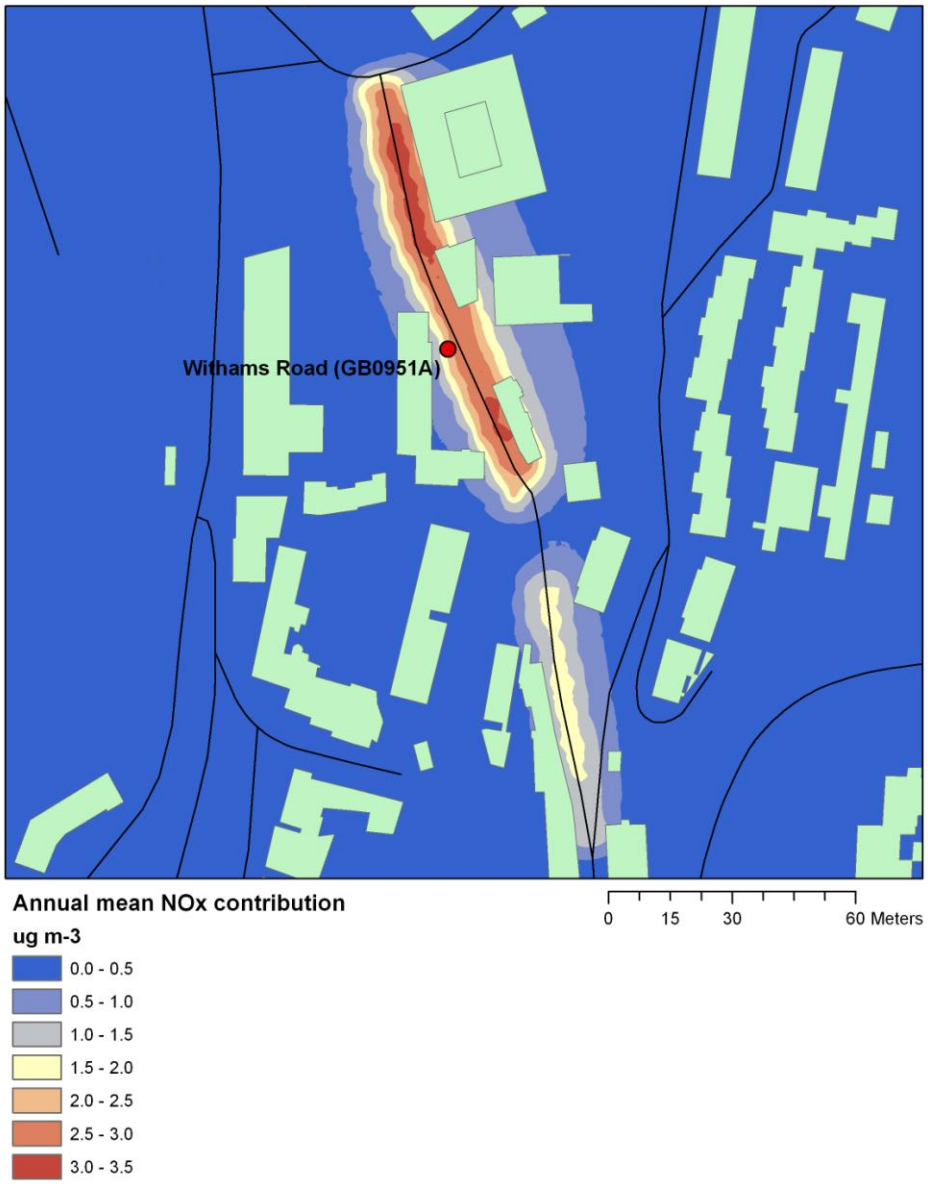


Figure 5-2 Modelled NO_X contribution from road traffic near the Witham's Road monitoring site



6 NO_X source apportionment

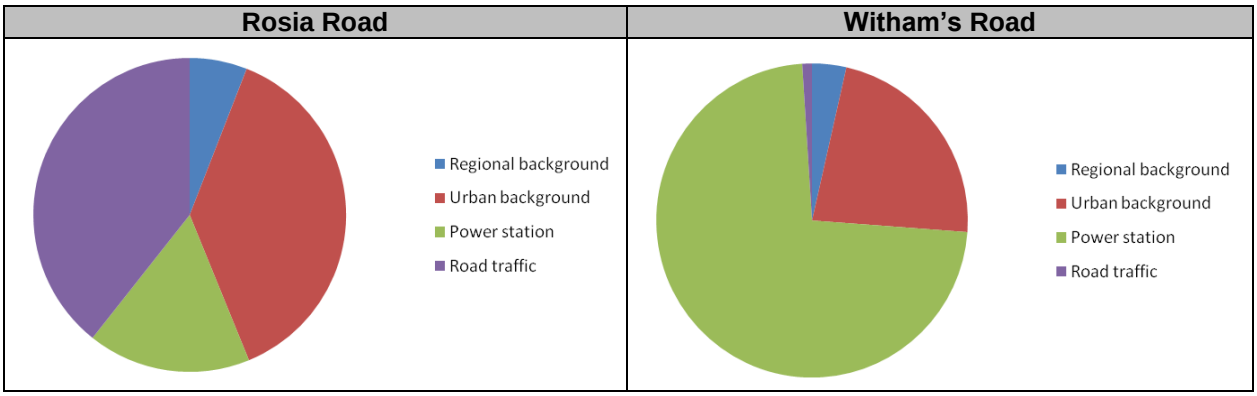
As noted in Section 1, a meaningful source apportionment exercise can only be undertaken on NO_X rather than NO_2. As a result this section summarises the apportionment for NO_X, in the reference year (2008) and then summarises the anticipated apportionment resulting from measures adopted by the Government of Gibraltar. This NO_X reduction is then used in Section 7 to demonstrate compliance against the annual mean NO_2 LV by the end of the time extension period applied for.

Table 6-1 and Figure 6-1 summarise the NO_X apportionment at Rosia Road and Witham's Road monitoring sites in the reference year. The measured concentrations for both monitoring sites are included in the table to place these contributions in the context of the whole and to demonstrate closure of the apportionment.

Table 6-1 Source apportionment for annual mean NO_X at Rosia Road and Witham's Road, 2008

Contribution	Concentration (µg m^{-3})	
	Rosia Road	Witham's Road
Measured concentration	89.0	149.0
Regional background	5.3	5.3
Urban background	33.7	33.7
Power station	15.0	108.5
Road traffic	35.0	1.5

Figure 6-1 Source apportionment breakdown at Rosia Road and Witham's Road, 2008



The regional background contribution was derived from an average of regional background sites from the Spanish mainland downloaded from the European air quality database, AirBase[15]. The sites used were Viznar (annual mean NO_X as NO_2 = 7.4 µg m^{-3}) and Barcarrota (annual mean NO_X as NO_2 = 3.1 µg m^{-3}). These sites are not close to Gibraltar but as a reflection of regional background they are representative. A closer site was available at Alcornocales but the NO_X (as NO_2) concentration for this site was 17 µg m^{-3}, inconsistently high compared with the other sites and is thought to be more industrial than an ideal regional background environment should be.

The urban background concentration was taken to be the measured NO_X concentration from Bleak House in 2008.

The power station contributions presented here are not consistent with those presented in Section 4. This was the result of a revision to how we quantified the contribution from the power station. A conventional apportionment conducted by subtracting estimated contributions of all the assessed sources from the measured concentration at each site should be close to zero i.e. all the sources have been accounted for and apportioned. In some cases the remaining concentration not accounted for

[15] http://air-climate.eionet.europa.eu/databases/airbase/

would be allocated as 'other', reflecting uncertainties in the modelled contributions or other small unquantified sources. Initial efforts to apportion the NO_X in this manner resulted in a large 'other' class at Witham's Road. This would suggest that there was an additional, unaccounted source at Witham's Road. This *would* typically be explained as sources that the assessment has not accounted for, such as shipping for example. However, the same method does not result in the same unapportioned NO_X at Rosia Road (the measured concentration was 1 µg m^{-3} lower than the sum of the estimated contributions), which should be similar to Witham's Road for such sources due to their proximity. Therefore, proceeding with this methodology did not produce realistic results at both sites and an alternative method was adopted in which the power station contribution was calculated by difference from the measured concentration minus the sum of the other estimated contributions. This permits the complete apportionment of the measured NO_X at both sites and results in a sensible representation of the contributions given local knowledge regarding the sources. This also produces results that are not reasonably consistent with the power station modelled concentrations presented in Section 4.1 – i.e. at Rosia Road the contribution from the power station changes from 16 µg m^{-3} to 15 µg m^{-3} under this method. At Witham's Road the difference is greater, changing from 70 µg m^{-3} under the conventional method to 108.5 µg m^{-3} under the new method. Despite this greater change, the value remains consistent with modelled concentrations at other nearby receptors presented in Table 4-1. Given issues regarding representing buildings and complex topography in the modelling, the power station model results were more uncertain than the quantification of the other contributions and apportioning the NO_X in this way is appropriate.

The road traffic contribution was taken from the modelling exercise presented in Section 5.

Table 6-2 presents the anticipated source apportionment resulting from the measures adopted in Gibraltar (i.e. the new power station and decommissioning of the existing power stations). The non-power station components are unchanged for the future but the power station component reduces to 2.5 µg m^{-3}. This value is the maximum modelled NO_X contribution from the AQC study based on a 40m stack and was selected for use in this apportionment to provide a conservative representation rather than the lower 0.1 µg m^{-3} modelled contribution at Rosia Road and Witham's Road monitoring sites.

Table 6-2 Source apportionment for annual mean NO_X at Rosia Road and Witham's Road resulting from adopted measures

Contribution	Rosia Road (µg m^{-3})	Witham's Road (µg m^{-3})
Regional background	5.3	5.3
Urban background	33.7	33.7
Power station	2.5*	2.5*
Road traffic	35.0	1.5
NO_X reduction from measures**	12.5	106.0

* as a conservative estimate this concentration represents the maximum modelled contribution from the new power station (the specific modelled contribution both at Rosia Road and Witham's Road was 0.1 µg m^{-3}, therefore this assessment marginally understates the impact of the new power station measure).

** the measures quantified in this assessment are the new power station only. An additional NO_X benefit will be associated with EURO standards and Gibraltar Traffic Plan but not presented here.

Though the analysis presented here demonstrates that the new power station alone is anticipated to result in significant decreases in measured NO_X concentrations, the authorities in Gibraltar are also pursuing additional measures aimed at reducing emissions from road traffic via the Gibraltar Traffic Plan. Further improvements to NO_X are anticipated over the time extension period resulting from technology improvements to motor vehicles due to EURO standards (not explicitly quantified in this assessment) and regional background concentrations due to emission controls and measures applied by surrounding Member States.

7 Ascertaining NO_2 from NO_X

Table 6-2 demonstrated a significant reduction in NO_X concentrations resulting from the power station measure adopted in Gibraltar. However a successful TEN application requires demonstration that NO_2 levels will achieve the Limit Values by the end of the extended deadline for compliance being applied for. Therefore it is necessary to translate reduction in NO_X shown in Section 6 in to NO_2. This has been undertaken for this assessment using an oxidant partitioning tool used for national air quality assessment in the UK which is based on an oxidant partitioning model developed by Jenkin[16] and implemented in the UK national modelling[17]. The tool has been designed for use in the UK and using it for Gibraltar is applying it outside the area for which is has been developed. However the method results in consistency with the measured NO_2 in the reference year (2008) but accounts for chemical process rather than relying on an empirical fit to a small amount of monitoring data.

The method requires the determination of a representative regional oxidant value and appropriate primary NO_2 (*f*-NO_2) values. Because Bleak House is not remote enough to adequately represent a regional background concentration, the regional oxidant was calculated in ppb as the sum of NO_2 and ozone concentrations from the two Spanish regional background monitoring sites (Viznar and Barcarrota) used to represent the regional background NO_X concentration for the source apportionment assessment in Section 6. This gives a realistic value of 39.3 ppb (the UK uses 35 ppb).

Witham's Road and Bleak House were both allocated a local oxidant concentration of 5% which was considered realistic given that neither is significantly affected by elevated *f*-NO_2 associated with road traffic emissions. Rosia Road, which is more affected by road traffic emissions was allocated an *f*-NO_2 of 10% to represent the balance of traffic on the road (see Table 7-1)

Table 7-1 Speed independent *f*-NO_2 factors for different road vehicle classes in Gibraltar

Vehicle class	*f*-NO_2 (%)
HGVs	12
Cars/Vans *	8.4*
Motorcycles **	4
Mopeds/Scooters **	4

* 8.4% taken from assuming: Petrol cars = 1.4 - 2.0 litres, Diesel cars > 2 litres, Vans = N1 Class III

** Mopeds/Scooters and Motorcycles – no specific information available therefore based on assumption that they are similar to other SI vehicles. Because NO_X emission factors for the two-wheeled vehicles are so small, this uncertainty will cause very little change to the primary NO_2 inventory for Gibraltar

Table 7-2 shows for the reference year how well the model determines NO_2 at each monitoring site based on the regional and local oxidant values selected and the NO_X concentration relative to the measured NO_2 concentration. This demonstrates that the tool performs well against measured concentrations in Gibraltar. Table 7-3 presents the estimated NO_2 based on a NO_X reduction scenario representing the decline in NO_X emissions due to the power station measures adopted in Gibraltar. This shows that both the exceeding sites in 2008 (Witham's Road and Rosia Road) are anticipated to be below the LV as a result of the power station measure. Bleak House has been included for completeness but is not expected to benefit from the power station measure because it is not significantly affected by the existing power stations.

[16] Jenkin, M.E. (2004). Analysis of sources and partitioning of oxidant in the UK-Part 1: the NOx-dependence of annual mean concentrations of nitrogen dioxide and ozone. *Atmospheric Environment*, **38**, 5117–5129.

[17] Grice, S.E., Cooke, S.L., Stedman, J.R., Bush, T.J., Vincent, K.J.,Abbott, J. and Kent, A.J. (2010). UK air quality modelling for annual reporting 2008 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. Report to the Department for Environment, Food and Rural Affairs, the Scottish Executive, Welsh Assembly Government and the Department of the Environment in Northern Ireland. AEA report. AEAT/ENV/R/2859 Issue 1 (under preparation)

Table 7-2 Calculation of NO_2 from NO_X by oxidant partitioning method, 2008

Site	NO_X (as NO_2, µg m^{-3})	Regional oxidant (ppb)	Local oxidant (*f*-NO_2) (ppb)	Estimated NO_2 (µg m^{-3})	Measured NO_2 (µg m^{-3})
Rosia Road	89	39.3	4.7	41.5	45.0
Witham's Road	149	39.3	3.9	57.4	53.0
Bleak House	39	39.3	3.9	26.6	26.0

Table 7-3 Calculation of NO_2 from NO_X by oxidant partitioning method, NO_X reduction scenario (power station measure)

Site	NO_X reduction (as NO_2, µg m^{-3})	Regional oxidant (ppb)	Local oxidant (*f*-NO_2) (ppb)	Estimated NO_2 (µg m^{-3})
Rosia Road	12.5	39.3	4.0	36.8
Witham's Road	106.0	39.3	1.1	22.1
Bleak House	0.0	39.3	1.0	26.6

8 Summary

8.1 Conclusions

- The existing OESCO and MOD power stations are by far the dominant sources of NO_X and NO_2 to Gibraltar.
- The proposed new power station being located at Lathbury Barracks coupled with the closure of the existing power stations (including Waterport power station near the frontier) would result in a significant decline in NO_X and NO_2 concentrations that is anticipated to ensure compliance with the annual LV for NO_2.
- While not explicitly quantified in this assessment, further NO_X (and associated NO_2 reductions) are expected from road vehicles due to EURO standards and the Gibraltar Traffic Plan. This will provide further 'headroom' between measured concentrations and the LV.

8.2 Recommendations

- It is recommended that the Government of Gibraltar, supported by the Gibraltar Environmental Agency proceed with a formal TEN application for the annual mean NO_2 LV, applying for an extension period to the end of 2014 (the maximum possible time extension period), in order to facilitate the completion of the large scale power station construction project.

- Implement the measures presented in the Gibraltar Air Quality Action Plan accompanying the formal TEN application – the new power station measure and Gibraltar Transport Plan are the relevant measures for NO_2.

- There should be careful consideration given to the process of closing down the existing power stations to ensure that there is no situation where the new power station running concurrently with the existing ones and therefore causing an additional rather than an alternative source of NO_X.

- Continuous monitoring over the coming period to demonstrate that the measures implemented are having the anticipated effect on concentrations and will result in compliance by the end of any granted extension period but preferably earlier. If concentrations do not decline as expected, it is recommended that due consideration is given to the implementation of additional alternative measures to complement those in force.

9 Acknowledgements

The following groups and agencies have made important contributions to the analysis underpinning this report:

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AEA group
329 Harwell
Didcot
Oxfordshire
OX11 0QJ

Tel: 0870 190 6401
Fax: 0870 190 6318