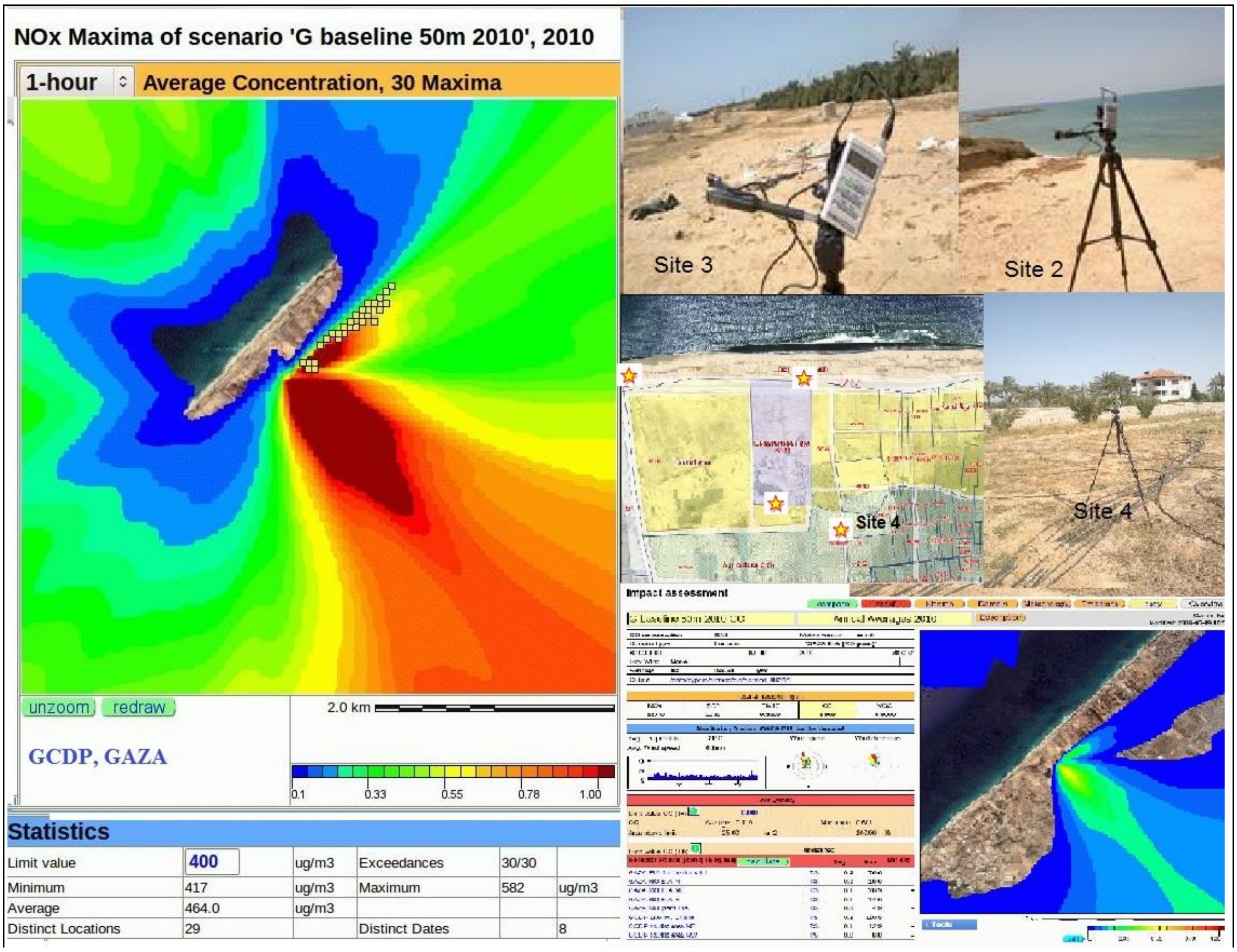
ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR THE GAZA CENTRAL DESALINATION PLANT

AIR DISPERSION & CO2 EMISSION STUDY



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Final Report

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Gaza Strip – Palestine

ANNEX IV: AIR DISPERSION STUDY

TABLE OF CONTENTS

TABLES

FIGURES

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

3D	three dimensional
AERMET	Meteorological pre-processor for ERMOD
AERMOD	USEPA standard regulatory Gaussian dispersion model
BETA	non-standard AERMOD parameter for low wind situations
BDL	Below Detection Limit
CAMx	Comprehensive Air Quality Model with Extensions
CRF	Common Reporting Format
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO2e	*Carbon* dioxide *equivalent,* signifies the amount of *CO2* which would have the *equivalent* global warming impact
COP 15	Conference of the Parties, Copenhagen summit, 2009.
COP 21	Conference of the Parties, also known as the 2015 Paris Climate Conference.
DF	Dual fuel (engines)
EC	European Commission
ECE	Economic Commission of Europe
EEA	European Environmental Agency
EMEP	European Monitoring and Evaluation Program
EPA	Environmental Protection Agency (US)
EIA	Environmental Impact Assessment
EIAPP	USEPA certificate fir diesel engines
EU	European Union
FNL	meteorological re-analysis data set
GHG	Greenhouse gas
GL	Giga Litre
IPPC	Integrated Pollution Prevention and Control, EU Directive
IMO	International Maritime Organization
MARPOL	International Convention: Prevention of Pollution from Ships
masl	meter above sea level
mcip	Meteorological-Chemical Interface Processor
MED	Multiple effect distillation
MSF	Multistage flash
$\mu g/m^3$	Microgram per cubic meter
mmif	Mesoscale Model Interface Program
MW	*Megawatt*
NCEP	National Center for Environmental Prediction, US
NFR	Nomenclature for Reporting
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
NO	Mono-nitrogen oxides
NO2	Nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
PBL	Planetary Boundary Layer
PBM	Photochemical Box Model
LCA	Life Cycle Assessment
PM	Particulate Matter
PM_{10}	Particles with a diameter less than 10 microns

$PM_{2.5}$	Particles with a diameter less than 10 microns
PSAAQ	Palestinian Standard for Ambient Air Quality
PUFF	USEPA Lagrangian/Gaussian puff model
PV	Photovoltaic
SECA	Sulphur Emission Control Area
SO2	Sulphur Dioxide
TSP	Total Suspended Particles
TVOCs	Total Volatile Organic Compounds
UNFCCC	The *United Nations* Framework Convention on Climate Change
UTM	Universal Transverse Mercator, map projection
WHO	World Health Organisation

EXECUTIVE SUMMARY

This simulation study evaluates the atmospheric environmental impacts and compliance with national and international air quality standards for a small desalination plant (GCDP) located close to the seashore of Deir El Balah governorate, near Al-Qarara town. The single 6.5 m high stack is positioned at 31.40267 N, 34.31731 (UTM: 625,500, 3,474,800), 11 masl).

The plant operates with electricity from a combination of three Wärtsilä (16 V34 DF) reciprocating internal combustion engines (7.6 MW each) , burning diesel fuel (gasoil) or natural gas and an optional supporting photovoltaic unit, designed to replace one of the three diesel engines. The total energy need/consumption is quoted at a slightly higher 24-25 MW. Using worst case assumptions, (emissions, meteorology) the dispersion modelling indicates that the dual fuel engines will not produce relevant emissions (in terms of ambient air quality standard violations, only NOx is relevant: estimated emissions amount to about 33 g/s). With the exception of NOx, summarized below, all expected maxima are orders of magnitude below the regulatory limit values, or, for the case of NO_2, do not exceed the maximum number of permissible exceedances per year (as defined in 2008/50/EC).

POLLUTANT	PERIOD	MAX	STANDARD	PERIOD	MAX	STANDARD
NO2/NOx	hour	**582**	400	year	**2.8**	100
SO2	hour	192	350 (EU)	24 hours	**67**	250
PM10	24 hours	**3**	150	year	**0.034**	70
CO	8 hours	**78**	10,000			

Table 1: Summary of compliance (2010 meteorology– worst case)

Period: *aggregation period* ***max:*** *maximum value simulated (in µg/m3)*
Standard: *applicable national AQ standard (in µg/m3)*

The NO_2 (simulated conservatively as NO_x) exceedances are limited to 8 events in 1 year out of the four tested. They occurred in **8 hours out of 35,040** simulated), with all exceedances in the immediate neighbourhood of the source. The EU air quality limits for NO_2 (2008/50/EC) define 18 “permitted exceedances each year”, which implies compliance by EU regulations. PM10 also complies to the PM2.5 standard, which obviously also guarantees PM2.5 compliance.. At the selected sensitive (populated) receptor location “Chalet”, no violation of any of the national air quality standards was predicted (considering the EU maximum number of annual exceedances).

Emissions of GHG: The annual CO2 equivalent (CO2e) emissions from GCDP estimated as 14,783 tons per year for production of 55 GL of desalinated water. That mean the life cycle assessment (LCA) of the greenhouse gas emissions from the production of 1 Giga Litre (GL) of water through GCDP is 268.7 tons of CO2e.

Mitigation options:
In principle, and without any detailed considerations of costs or technical feasibility, each of the options would be sufficient to reach complete compliance. They include:

- Change of fuel from diesel to natural gas (dual fuel engines)
- Reduction of the use fossil fuels, use of alternative, renewable energy (photovoltaics, wind energy)
- Increasing the stack height (local improvement only)
- Supplying electricity from the grid (local improvement only).

In summary, given the size and location of the emission source, it poses no major environmental hazard or impacts; several alternative mitigation options are available to ensure full compliance even under rare, extreme meteorological conditions (NO_2).

1. INTRODUCTION

The target of this study is the numerical simulation of a small point source near Gaza as part of a more comprehensive EIA. This includes simulation of both multi-year meteorological conditions as well as the dispersion and ambient concentration in a 5 km domain around the source and at selected "receptor points", using a standard USEPA regulatory model, AERMOD, and MM5/mmif for the dynamic downscaling of meteorological data from synoptic re-analysis data sets (NOAA/NCEP).

The study evaluates the atmospheric environmental impacts and compliance with national and international air quality standards for a small desalination plant (GCDP). The plant is located south of **Gaza City**, close to the seashore of **Deir El Balah** governorate, near **Al-Qarara** town located north of Khan Yunis governorate of the southern Gaza Strip. Al-Qarara had a population of over 16,900 inhabitants in mid 2006.

The single stack is positioned position at 31.40267 N, 34.31731 (UTM: 625,500, 3,474,800), in a coastal location (11 masl), and thus subject to variable winds (sea breeze). The nearest sensitive receptor is a residence ("Chalet") located northeast of the GCDP (Site # 4)

The plant operates with electricity from a combination of three Wärtsilä (16 V34 DF) reciprocating internal combustion engines with a nominal power of 7.6 MW each, burning diesel fuel (gasoil). There is consideration of an optional supporting photovoltaic unit, designed to replace one of the three diesel engines. As an alternative fuel, the engines can also operate on natural gas.

The study uses the classical USEPA regulatory Gaussian model AERMOD (latest release 15181, see also: (https://www3.epa.gov.scram001/dispersion_prefrec.htm) in combination with hourly 3D re-analysis meteorology (reference year: 2014) and several alternative years (2008-2011) to analyse the inter-annual variability. Alternative pre-processing programs (mcip, mmif) for the re-analysis meteorology will be used and compared. Pollutants covered are SO2, NO2/NOx, PM10, CO.

For critical periods (low wind, low PBM) alternative models (Eulerian CAMx, Lagrangian PUFF) will be used for cross-checking of results.

AERMOD will be used, with alternative emission estimates, in its standard regulatory form, but alternative low-wind corrections (BETA parameters) will be employed for extreme events.

Around the basic annual/hourly simulation runs for the reference year 2014 and worst case emission assumptions, a set of alternative assumptions on meteorology (alternative years) fuel/emissions, stack parameters, and model resolution will be explored in a range of sensitivity analysis experiments to improve the reliability of the basic impact simulation.

In parallel to this initial inception report and the final EIA report, an on-line version with all data used and generated and the model scenarios and detailed results with interactive analysis and display of the results is provided at http://www.ess.co.at/AIRWARE/GAZA (user name and password protected access).

2. LIMITATIONS OF THE STUDY

The study uses the most commonly used regulatory model (USEPA AERMOD), a steady-state Gaussian model on an hourly basis with one year re-analysis meteorological data (2014, center of the model domain), and three additional years (2008,2009,2010) for comparison.

The study thus shares all the assumptions (and shortcomings) of the steady-state Gaussian model approach, which can create extreme results under very low wind or PBM contitions, for which non-standard (beta) parameters are used.

Emission data are estimated using EEA/EMEP emission factors and engine data; fuel quality data provided vary by an order of magnitude for sulphur content (from 0.91 to 0.09%) , so a conservative correction factor on the EEA data for the SO2 estimate (*10) is used.

NO2 (as well as CO) are subject to photochemical reactions; however, the simulations have used NOx (conservative) as a "worst case" assumptions: compliance with NOx against NO2 standard guarantees NO2 compliance. The same approach was used for PM2.5/PM10.

Background data are based on a single day of observations available; No local emission data are available.

Scenarios simulated represent "worst case" and "most likely" combinations of assumptions for normal operating conditions, and use a one year (hourly resolution time frame.

3. AIR QUALITY REFERENCE STANDARDS

Predicted air quality is compared against Palestine national Standard and EU Standards for different substances and aggregation periods (1-hour, 8-hour, daily and annual).

Pollutant	Unit	Period	Palestine National Standard	EU
NO_2	µg/m^3	1 hour	**400**	200
		1 year	**100**	40
SO_2	µg/m^3	1 hour		350
		24 hours	**250**	125
		10 minute		
PM_{10}	µg/m^3	24 hours	**150**	50
		1 year	**70**	40
$PM_{2.5}$	µg/m^3	24 hours		
		1 year		25
CO	µg/m^3	8 hours	**10,000**	10,000

Table 2: Air Quality Reference Standards

NOTE 1: NO_2 will be approximates by the conservative NOx (conservative estimate).

NOTE 2: EU standards foresee an allowable number of annual exceedances, namely SO_2, hourly: 24; SO_2, 24 hours: 3; NO_2, hourly: 18; PM10, 24 hours: 35.

As per Directive 2008/50/EC, Annex 14, limit value for PM2.5 yearly average applicable in 2015 is 25 µg/m^3 and 20 µg/m^3 in 2020.

An additional reference or NO_2 is the IPPC (2008/1/EC) requirement of a maximum of 3% increase over the annual mean limit value, or 1.2 µg/m^3, or, converted to the national limit, 3.33 µg/m^3 (based on 100 µg/m^3 instead of the EU annual average NO_2 limit of 40 µg/m^3 . With the absolute maximum annual average (2008 meteorology) of 2.8, this is in compliance with an analogue standard based on the national limit value as well.

4. PROJECT LOCATION AND MODEL DOMAIN

The project and model domain are located around the emission source at: 31.40267 N, 34.31731 (UTM: 625,500, 3,474,800), East of Deir al Balah, and North of Al-Qarara.

The model domain is defined by a 5 by 5 km box with the source centred in it.

As part of the sensitivity analysis, we also use a 10 by 10 km outer domain, while the meteorological model uses a series or larger, nested domains

Figure 1: Location of CGDP Site

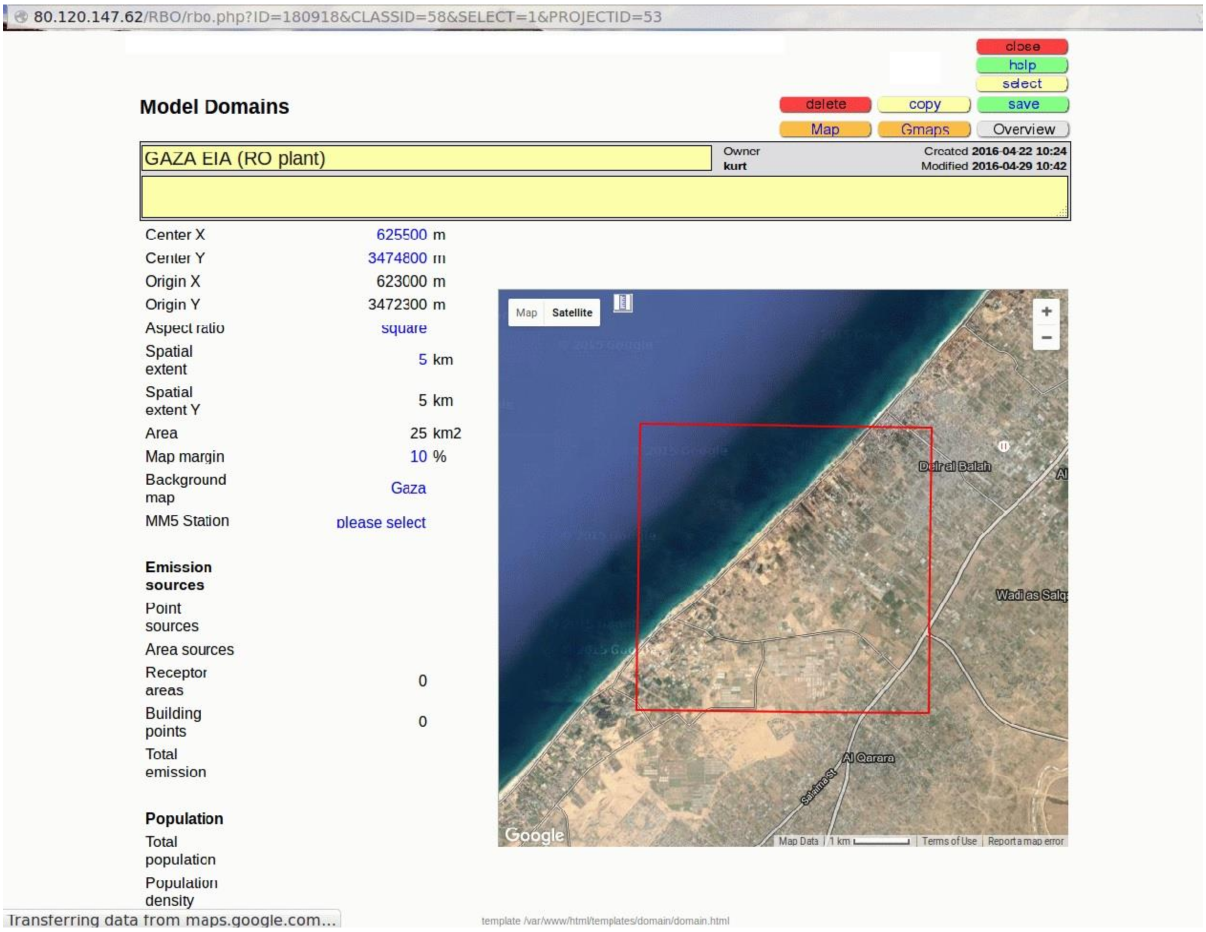


Figure 2: 5x5 km model domain alternatives from 2 to 10 km were also tested

Model resolution

The final EIA runs are run at a nominal 50m resolution (regular grid of 10,000 receptor points), for screening level analysis resolutions of 100 meters (2,500 receptor points) are used. For comparison and sensitivity analysis, 20 m grid spacing was also tested. The meteorological model for the inner domain is run at a 3 km resolution.

5. EMISSION SOURCE

The emission source is a single stack (height: 6.53 m, diameter: 1.7m) that combines the flue gas from 3 or 2 of the Wärtsilä 16V34 DF engines, nominal power output of 7.6 MW each, respectively.

Sensitivity analysis is used to explore the role of stack dimensions.

The emissions are estimated with alternative methods:

- Tier 2 estimates based on EMEP/EEA 2014 emission factors NFR code 1.A.1.a (Public electricity and heat production, Large stationary CI reciprocating engines, gas oil and other liquid fuels), EMEP/EEA air pollutant emission inventory guidebook- 2013. This leads to an emission estimate for NOx for three engines operating with diesel fuel of 33.4 g/s.
- Keane et al (2000) list average PM_{10} emissions from off-road diesel engines at approximate one order of magnitude below the NOx values, which is in close agreement with the EMEP/EEA values.
- Emission limits and flue gas volumes.
- Fuel consumption and fuel properties.

For the EIA run, the "worst case or" "most likely" assumptions are used. Sensitivity analysis is used to explore the range of alternative emission estimates.based on combinations of alternative parameters where applicable, and possible alternative configurations (use of supporting photovoltaics replacing one of three diesel engines, future use of natural gas).

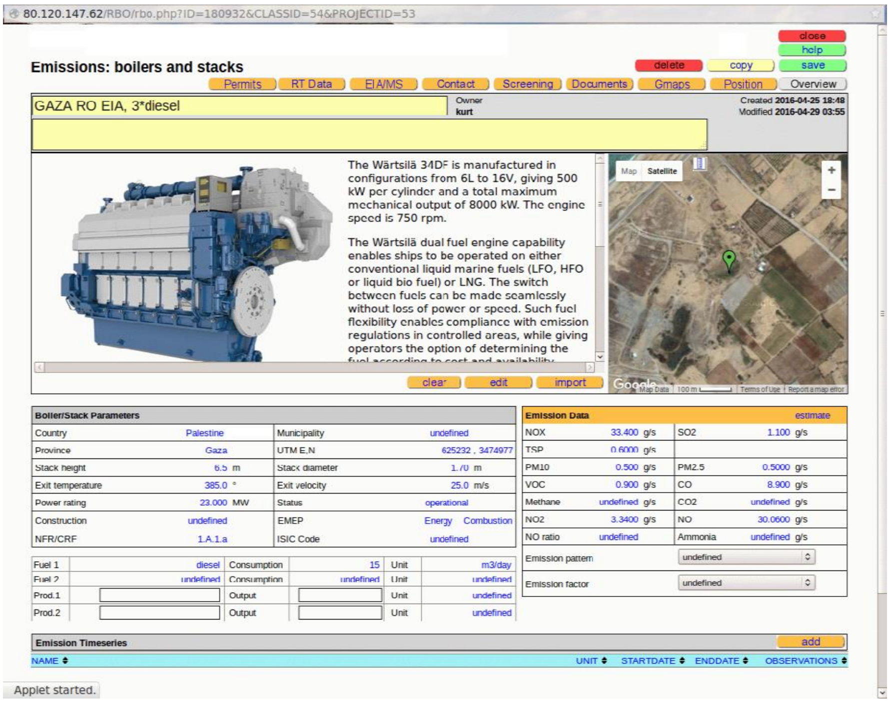


Figure 3: Source representation from the "emission inventory

Basic model assumptions include a flue gas temperature range of 385-440, °C and an exit velocity of 25m/s (at full power).

The product description for the Wärtsilä 16V34 DF engines states:

1. Exhaust Emissions

Exhaust emissions from the dual fuel engine mainly consist of nitrogen, carbon dioxide (CO_2) and water vapour with smaller quantities of carbon monoxide (CO), sulphur oxides (SO_x) and nitrogen oxides (NO_x), partially reacted and non-combusted hydrocarbons and particulates.

2. Dual fuel engine exhaust components

Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. In a dual fuel engine, the air-fuel ratio is very high, and uniform throughout the cylinders. Maximum temperatures and subsequent NO_x formation are therefore low, since the same specific heat quantity released to combustion is used to heat up a large mass of air.

Benefitting from this unique feature of the lean-burn principle, the NO_x emissions from the Wärtsilä 34DF are very low, complying with most existing legislation. In gas mode most stringent emissions of IMO, EPA and SECA are met, while in diesel mode the dual fuel engine is a normal diesel engine. In the following table 1 there are some examples of the typical emissions levels of a 34DF engine. See, for example:

- https://www.dieselnet.com/standards/us/stationary_nsps_ci.php; and
- https://www.dieselnet.com/standards/us/nonroad.php#tier3

Relevant emission standard would be (in g/kWh): CO: 3.5; NMHC+NOx: 6.4; PM: 0.2 (2006); NOx: 9.2 (2000). Tumeh (2011) states for Palestinian emission standards: “Lack of official standard or maximum acceptable level of Air Pollutants in the Palestinian Territory”. This (informal) presentation from the Palestinian Central Bureau of Statics significantly does not contain a single number.

Emission	100% load	75% load
NO_x	1.3	1.4
CO_2	460	469

Table 3: Typical emissions for Wärtsilä 34DF engine in gas operating mode, Typical emission levels* 100% load 75 % load (g/kWh)

Note: The CO2 emissions are depending on the quality of the gas used as a fuel. To reach low emissions in gas operation, it is essential that the amount of injected diesel fuel is very small. The Wärtsilä DF engines therefore use a "micro-pilot" with less than 1% diesel fuel injected at nominal load. Thus the emissions of SOx from the dual fuel engine are negligible. When the engine is in diesel operating mode, the emissions are in the same range as for any ordinary diesel engine, and the engine will be delivered with an EIAPP certificate to show compliance with the MARPOL Annex VI.

Emission limits of the Palestinian draft National Standard (Annex) at 400 mg/Nm^3, and reference to the German TA Luft at 1,330 mg/Nm^3. Exhaust gas flow is given with 11.7 (no units given, assuming: Nm^3/s. This would translate into upper limits of 4.7 g/s and 15.6 g/s NOx emissions. Baseline estimates (3 diesel engines used) based on 3*7.6 MW and EEA emission factors for reciprocating diesel engines (NFR/CRF 1.A.1.a yields 33.4 g/s).

6. METEOROLOGICAL INPUT

The air quality models used (primarily the regulatory Gaussian model (AERMOD) are driven by 3D dynamic (hourly, 3 km resolution) nested grid (three levels of nesting) re-analysis data based on the dynamic downscaling of NOAA/NCEP FNL data.

Station data for AERMOD/AERMET are extracted with alternative pre-processing tools (MCIP, MMIF).

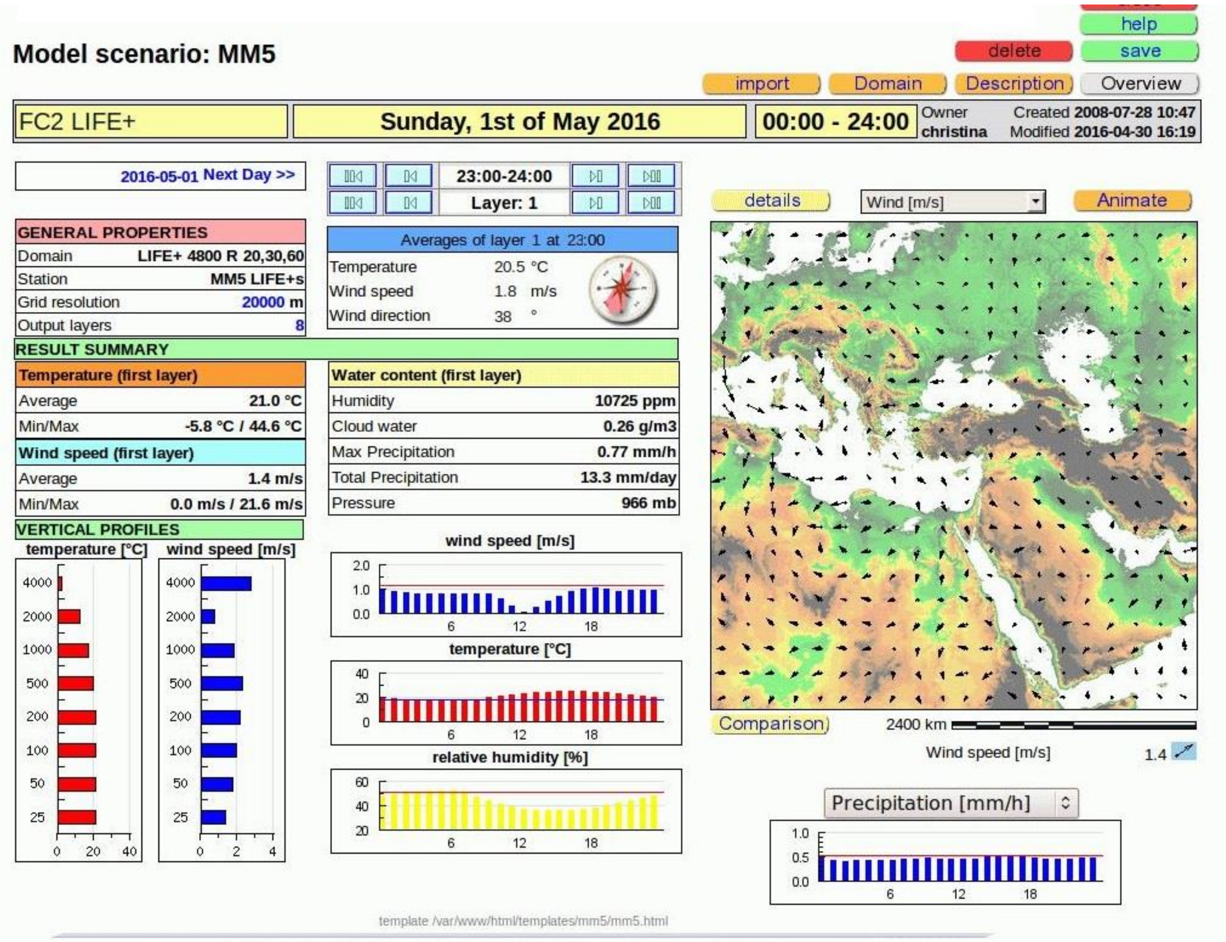


Figure 4: Meteorological model (MM5) master domain

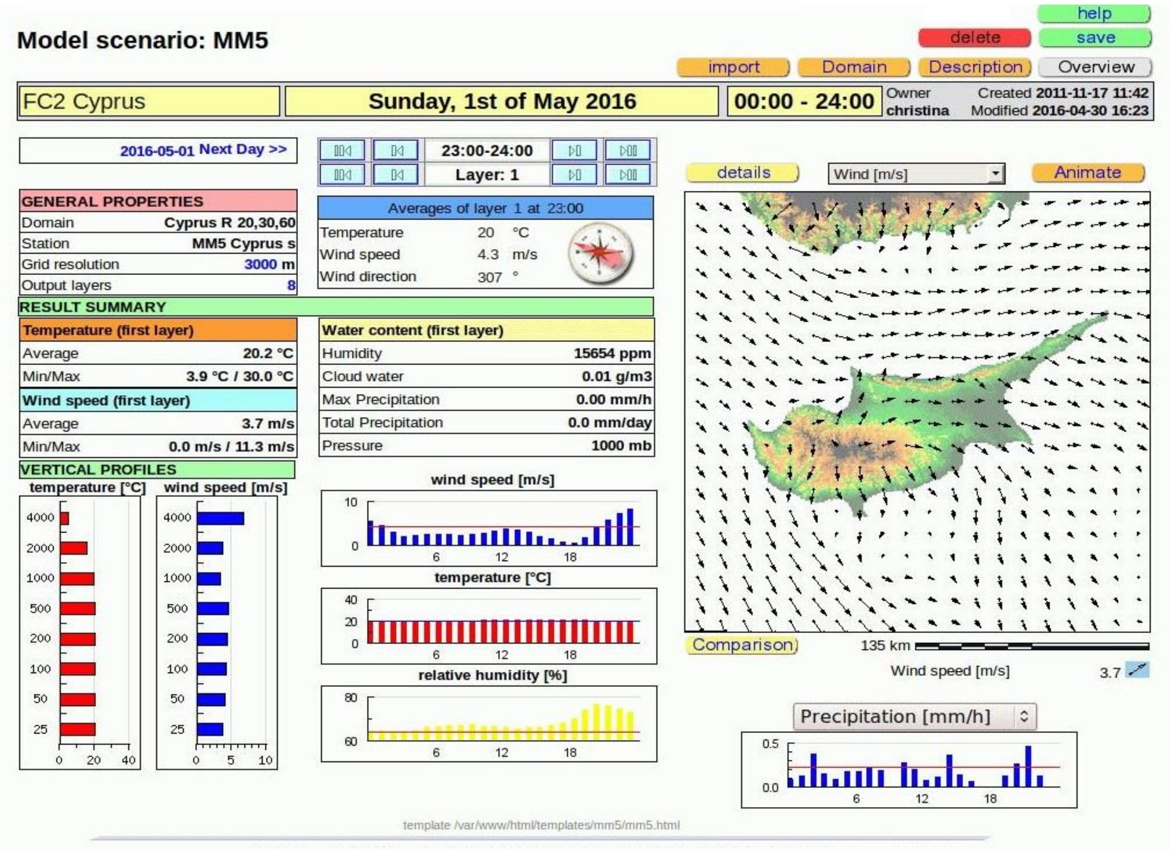


Figure 5: Meteo domain Cyprus (Eastern Mediterranean)

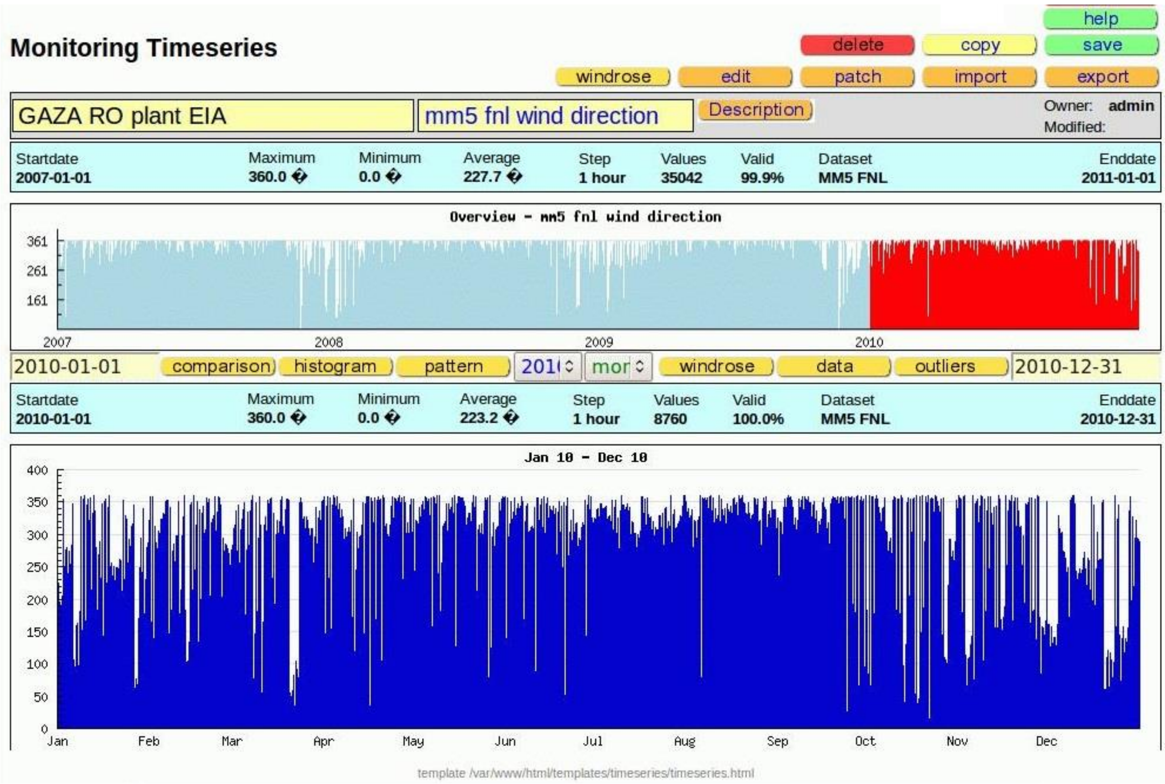


Figure 6: Virtual monitoring station GAZA EIA, time series 2007-20111, wind direction

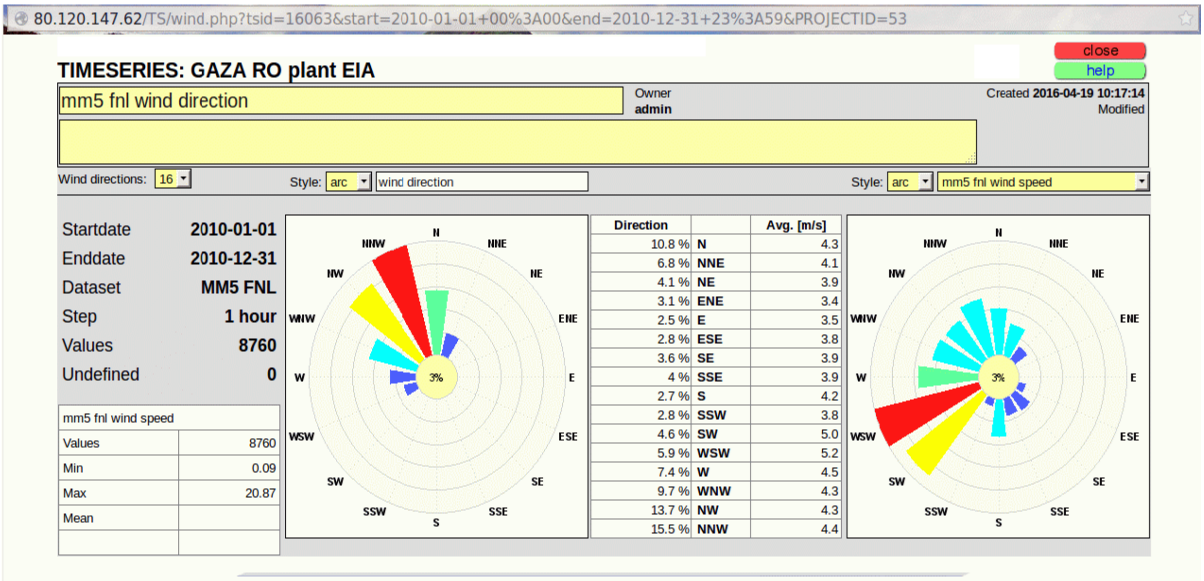


Figure 7: Wind roses, 2010 (center of the model domain)

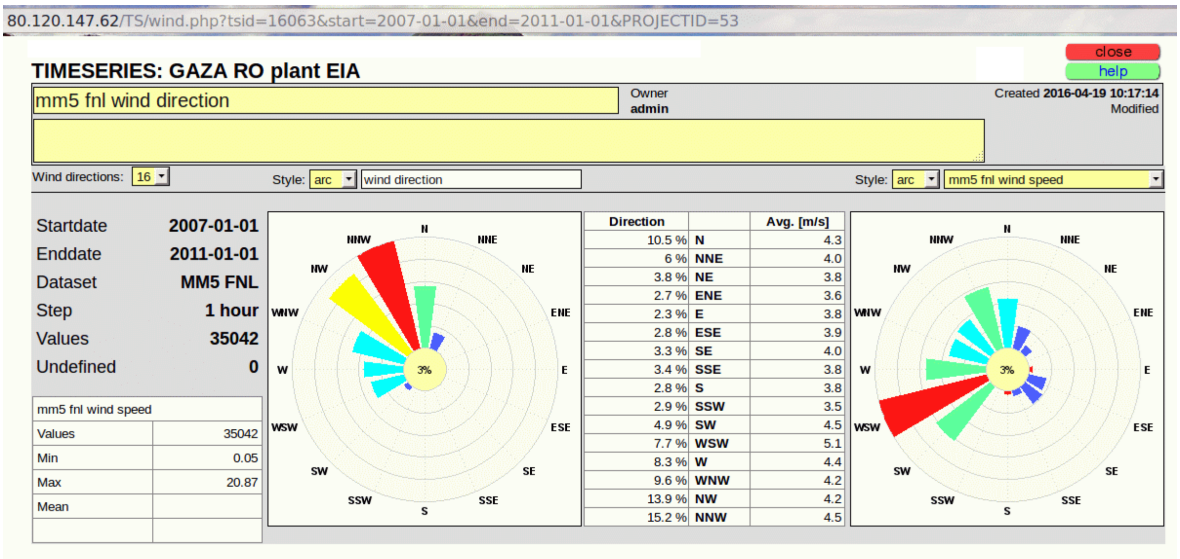


Figure 8: Wind roses, 2007-2010 (center of the model domain)

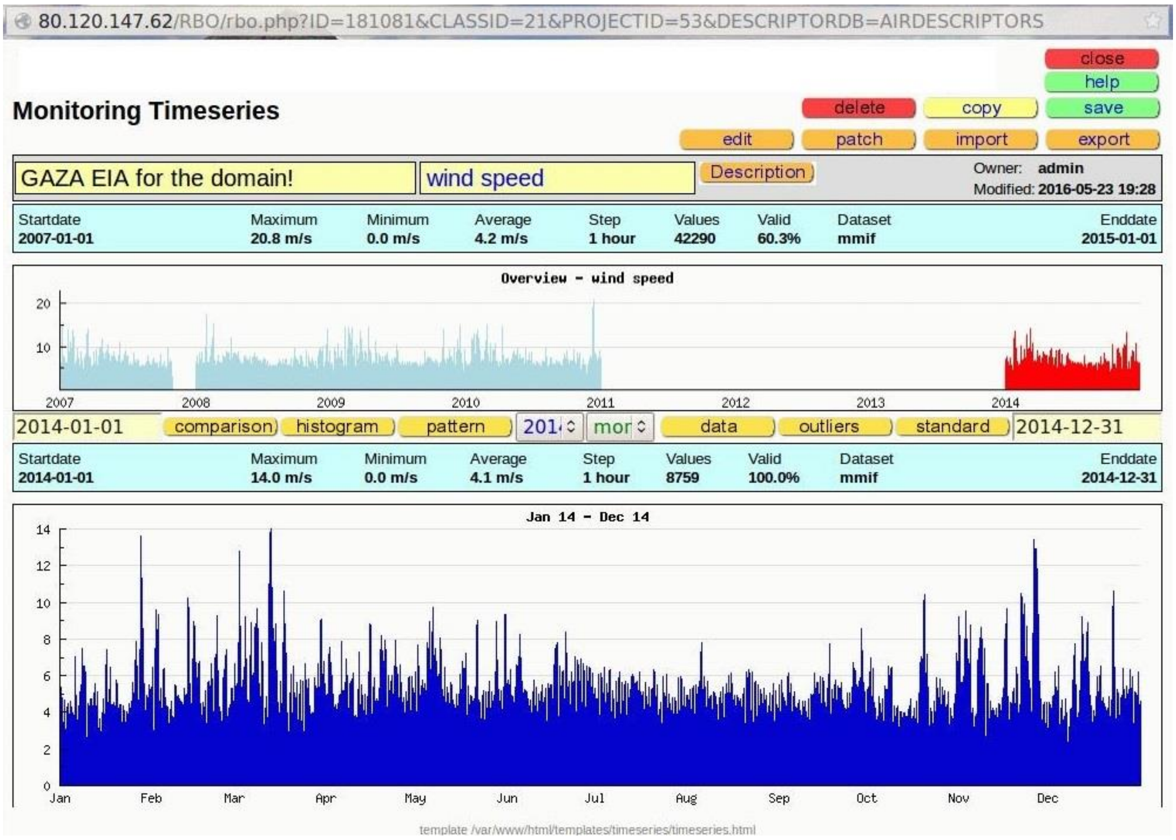


Figure 9: Wind speed 2014

7. METEO DATA USED

This study was performed under considerable resource limitations. No mete-orological data of the required hourly resolution were provided; therefore, so "site specific" data from available (2008-2010) regional re-analysis data, (LIFE project PM3, CY/000252) were used for the the regional model MM5 to generated local data for the domain using mmif for AERMOD input. An addi-tional year, 2014, was specifically run for this study. Results indicate that giv-en the near complete compliance, additional years of meteorology would hardly change that basic outcome. To analyse the effects of inter-annual variability of concentrations/compliance due to inter-annual variability of the weather, the baseline was run for a number of years: 2014 (reference), 2010 2009, 2008. Wind speed data in m/s, ground layer (2m).

Year	Wind speed avg. (m/s)	Wind speed max (m/s)	Hours < 1 m/s
2014	4.2	14.0	121
2010	4.2	20.8	318
2009	4.3	14.8	244
2008	4.2	17.5	306

Table 4: Wind speed data

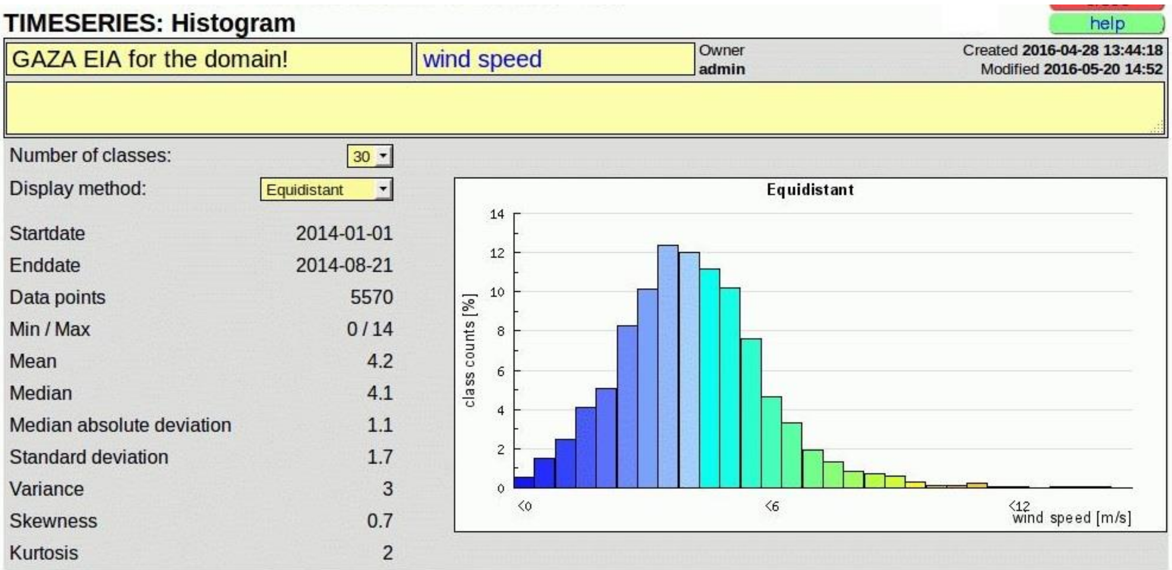


Figure 10: Wind speed histogram 2014

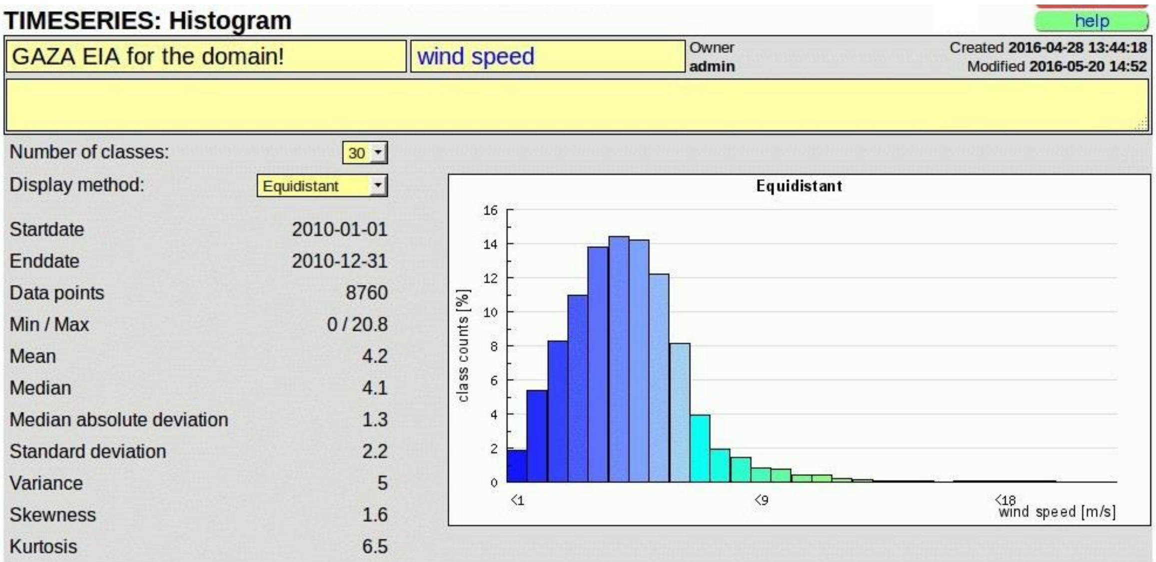


Figure 11: Wind speed histogram 2010

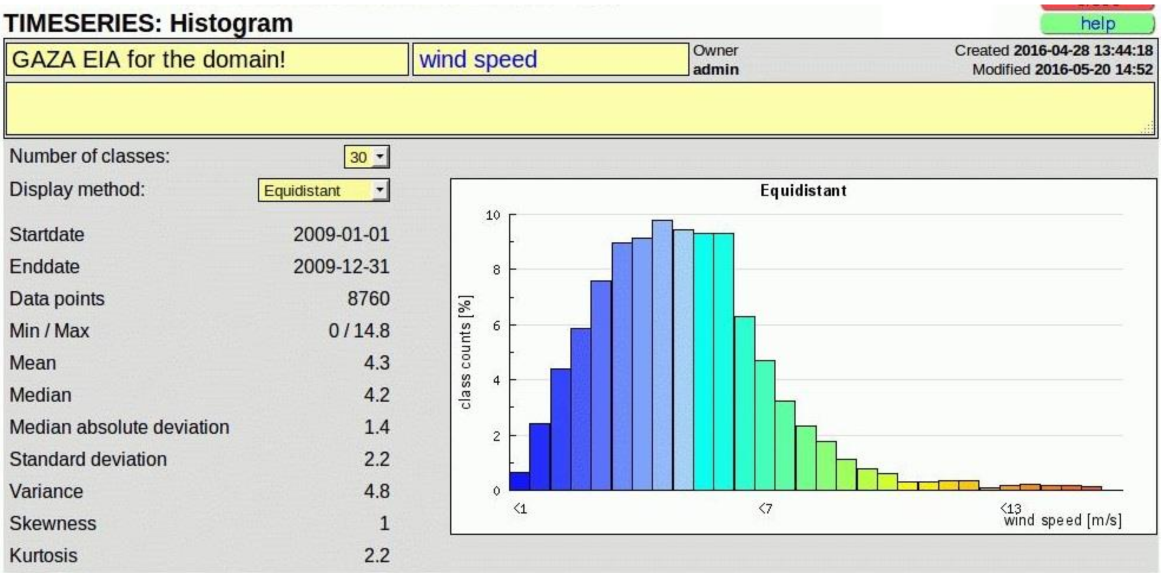


Figure 12: Wind speed histogram 2009

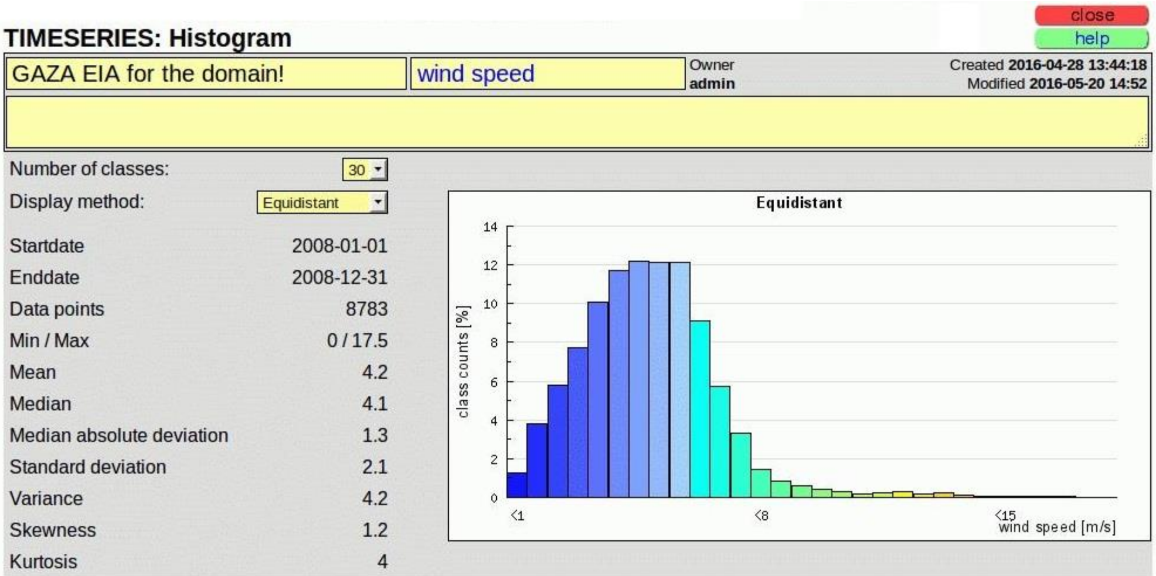


Figure 13: Wind speed histogram 2008

MM5 output (using NCEP/FNL global re-analysis data) is converted by MCIP (Otte and Plaim, 2009; www.cmascenter.org) into MCIP meteorological data format (= CMAQ input format), which in turn is converted by MCIP2AERMOD (Davies et al, 2008; https://launchpad.net/mcip2aermod/trunk) into AERMOD-ready surface and profile files.

An alternative program (used here) is MMIF, the Mesoscale Model Interface Program (Environ, 2015).

8. MODEL RESULTS: ANALYSIS AND DISPLAY

Basic model results are the hourly predicted concentrations for the 62,500 point receptor grid for each of the pollutants considered (8,760 solutions per year) for the reference (2014) and the three test years (2008 – 2010).

Results include the

- Emission estimates, including CO2 based on standard EU and USEPA emission factors for diesel
- Annual averages over the model domain, color coded matrix display
- lists and locations of the 30 maxim for hourly, 8 hourly, daily, and annual results
- Receptor grid display and user defined isolines with the associated areas, optional population exposure
- Statistics of compliance and violations
- Concentration time series of additional user defined "sensitive receptor points"
- Individual (24 hours) simulations for extreme events with hourly thumbnails and models runs with alternative models where applicable
- Direct comparison of alternative scenarios (results matrices)

It is important to note/understand that air quality standards as defined are only meaningful (in absolute terms) for any (set of) well defined sensitive receptor locations. Any domain and resolution (number of grid points) dependent values obviously vary with these (arbitrary) model parameters, but also between years.

A more meaningful analysis of compliance would require a well-defined set of receptor locations as "absolute" reference for the compliance evaluation independent of (variable) with resolution distance from the source.

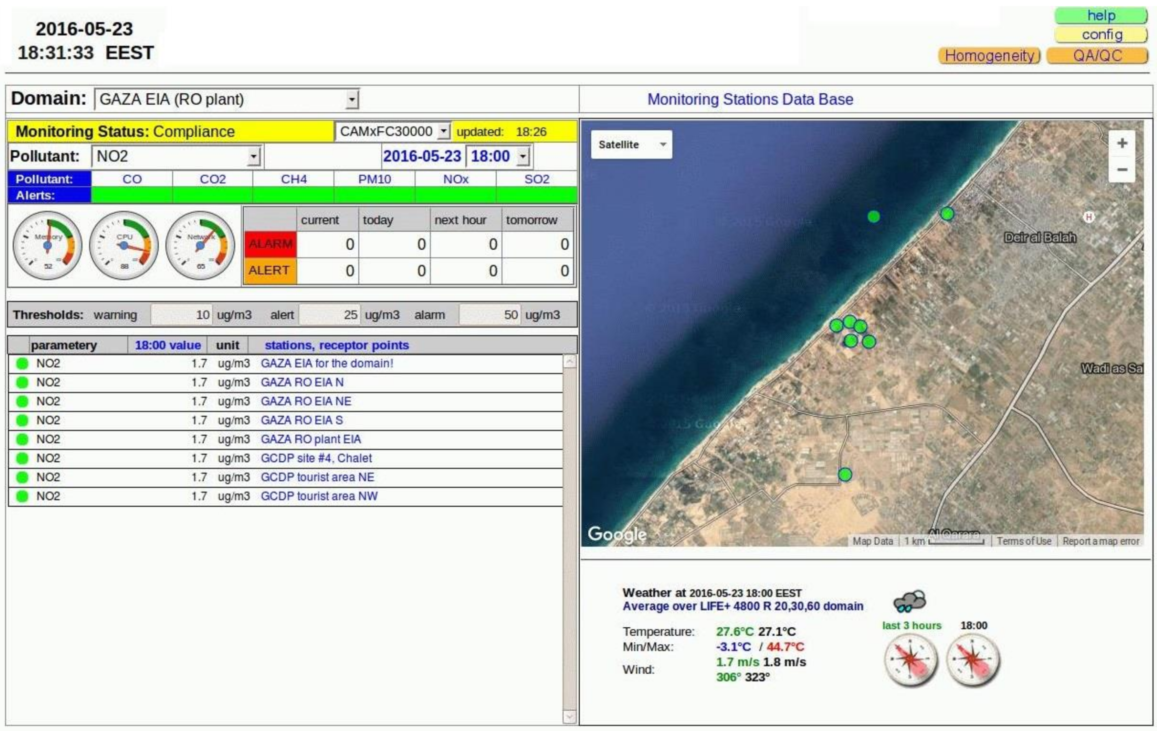


Figure 14: Local domain and arbitrary receptor points

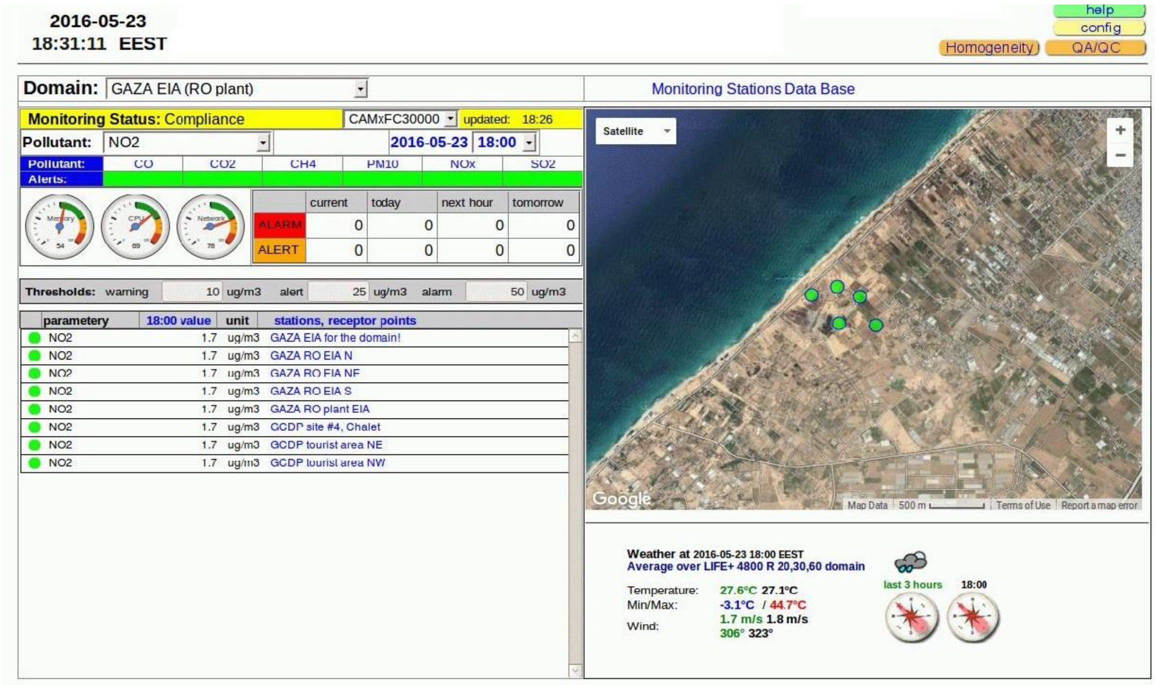


Figure 15: Local domain, receptors, zoomed

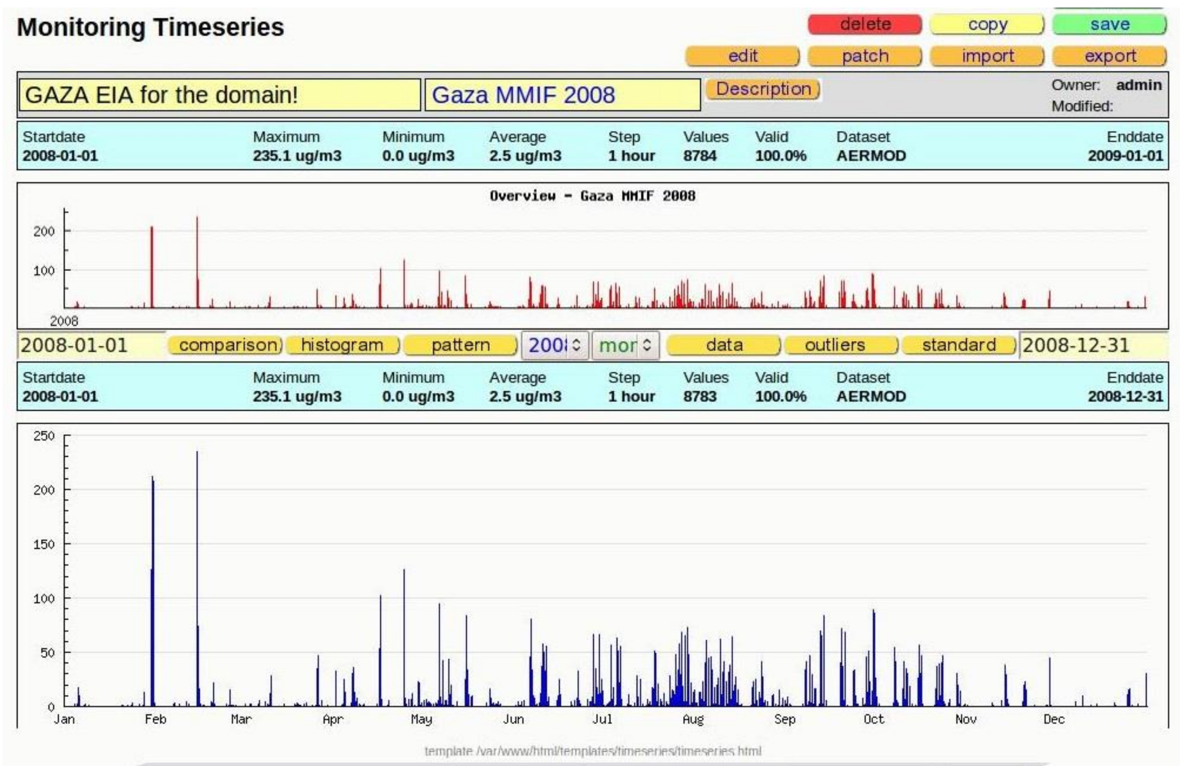


Figure 16: NOx time series (hourly), central receptor

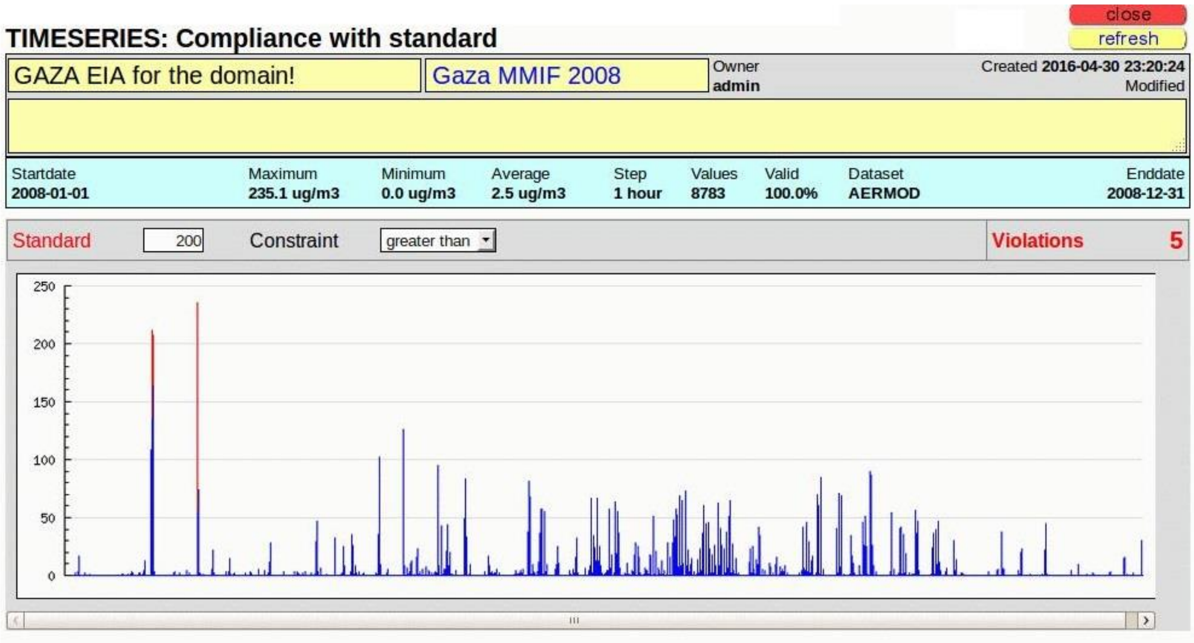


Figure 17: Filtering time series data from the receptor location for exceedances

9. EIA SCENARIOS, SIMULATION RUNS

To assess the air quality impacts of the desalination plant power generation unit, a number of scenarios (combination of assumptions) were defined and simulated and compared. These assumptions and the simulation results are described below. Each scenario was run for one year, with hourly resolution, i.e., 8760 hourly steady state solutions per year, with on average 10,000 receptor grid points (5 km domain with 50 m grid spacing).

10. BACKGROUND VALUES

Very little data (restricted to only one or two days of sampling) are available on local monitoring data as the basis for estimating background air quality locally. However:

- The area is covered by the (low resolution) regional EMEP emission data set (50 km grid) compiled and maintained by the EU in the WebDab EMEP data base (www.ceip.at/webdab_emepdatabase/)
- Within the operational daily simulation of a European/Eastern Mediterranean domain of 4,800 km (originally within the LIFE+ project PM3: see: http://www.ess.co.at/LIFE) the Gaza EIA domain is also covered with daily forecasts with hourly resolution.

Average background concentration for NOx and SO2 are reported in simple graphical format only (Figure 1& 2), the NOx concentration ranged between 17 and 47 µg/m^3 for different locations in Gaza Strip, and the monthly averages of SO2 concentrations for 2005 ranged from 80 to 120 µg/m^3 (EPRI, 2006). With Comparison of some related monitoring studies in the region (e.g. Damascus) show that a short-term monitoring of air pollutants for 15 selected sites in Damascus city has been investigated during the year 2000. The overall (24-h) average concentrations of the previous five pollutants were determined. The calculated concentrations were about 125 µg/m^3 for PM10, 39 µmg/m^3 for SO2, 49 µg/m^3 for NO2 and 2.8 mg/m^3 for CO. In that reported study, the particulate with less than 10-micrometer size (PM10) were the most effective pollutants in the air of Damascus city (*Meslmani, 2004*).

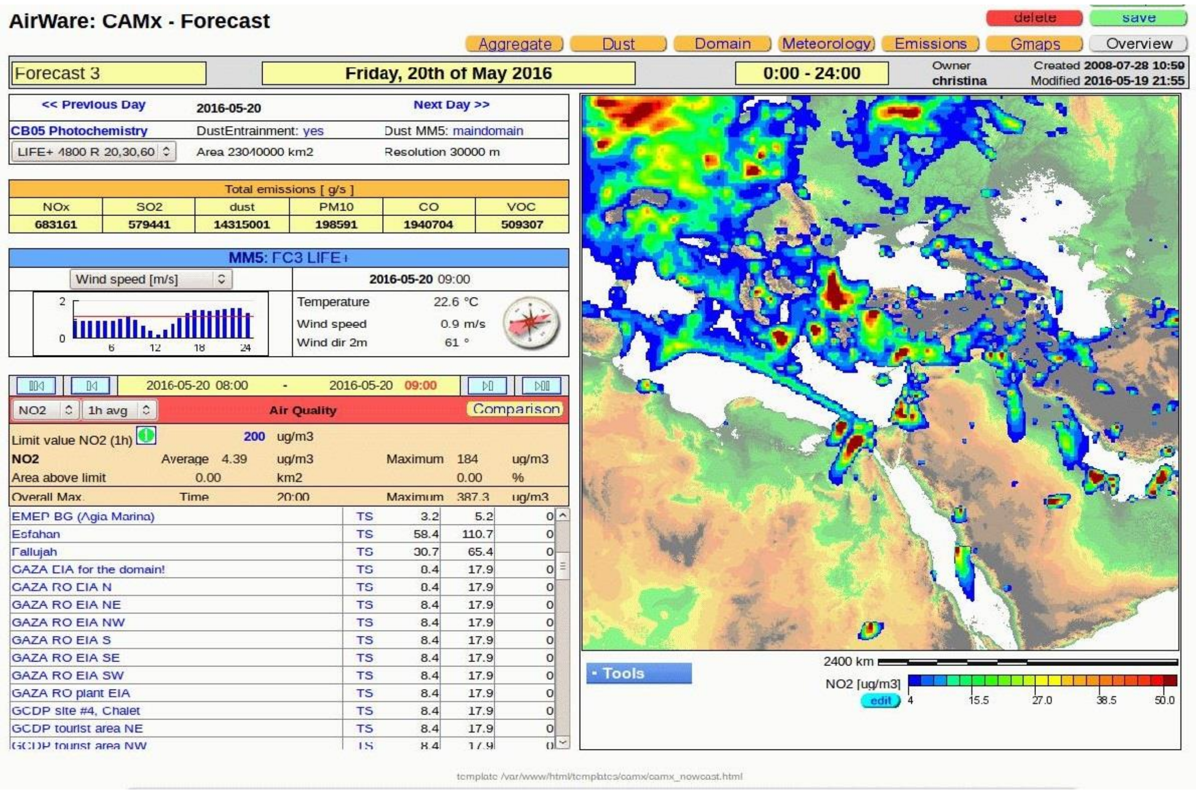


Figure 18: NO2 background concentration using EMEP emissions (CAMx model results)

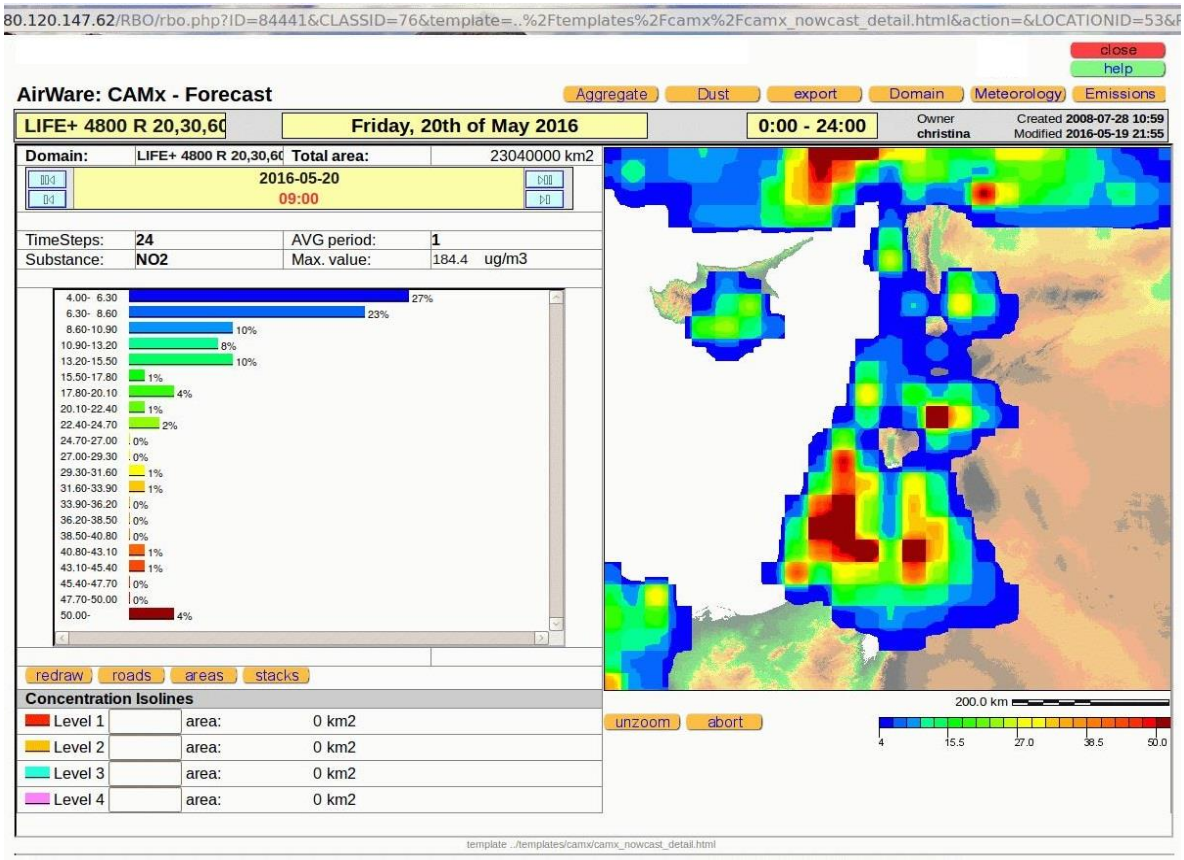


Figure 19: Zoomed to the case study region, CAMx model results EMEP + local tier 1 emissions

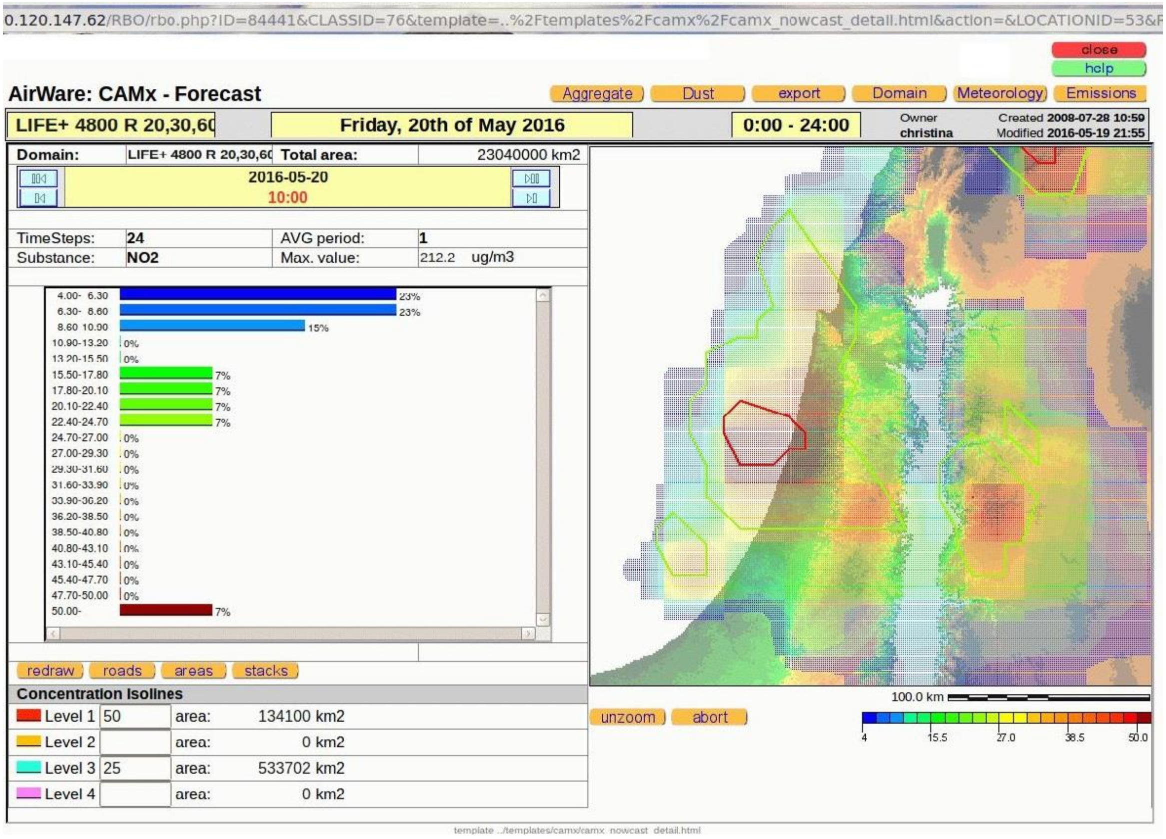


Figure 20: Zoomed detail, CAMx, EMEP + local tier 1 emission

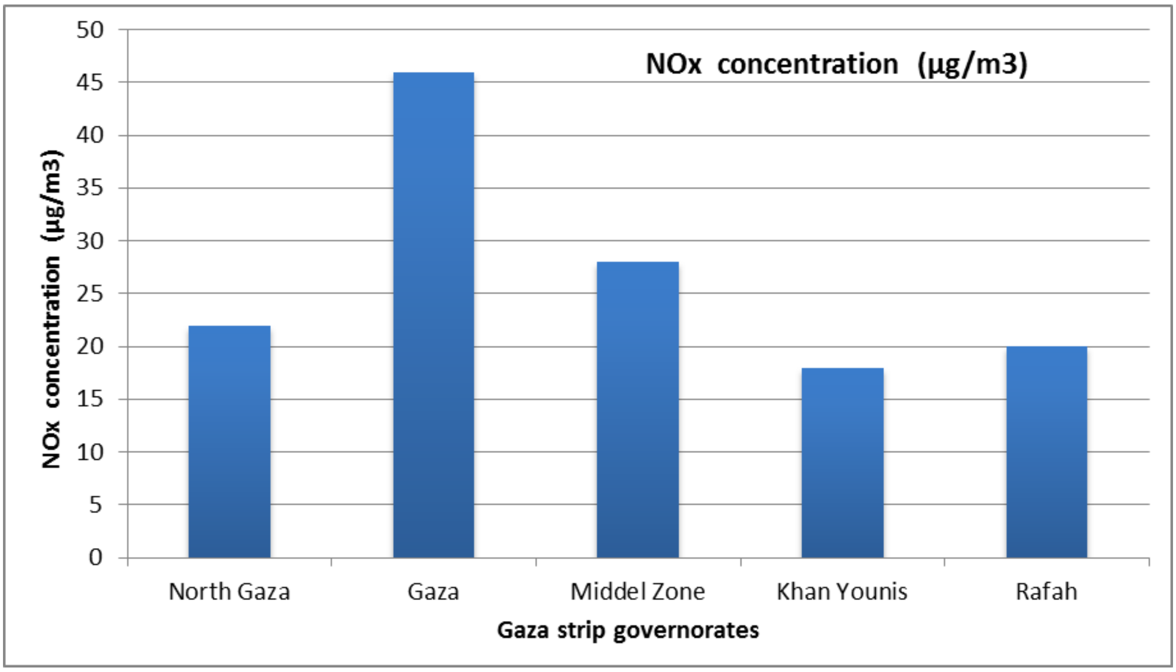


Figure 21: Concentration of Nitrogen oxides (µg/m3) in several Gaza Governorates in year Dec 2005, source (EPRI, 2006)

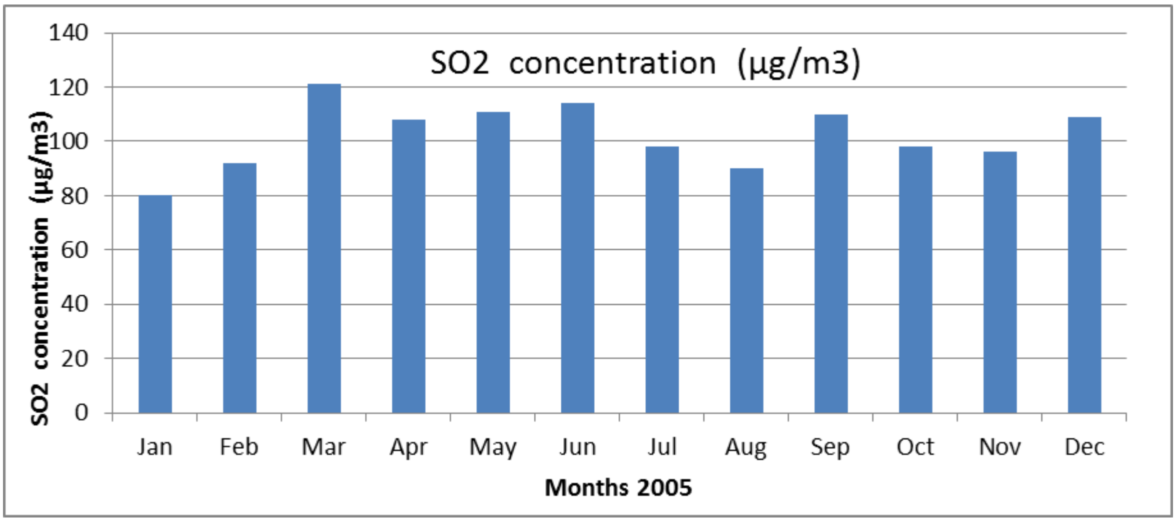


Figure 22: Concentration of Sulphur dioxide (µg/m3) in Middle zone of GAZA from Jan -Dec 2005, source (EPRI, 2006)

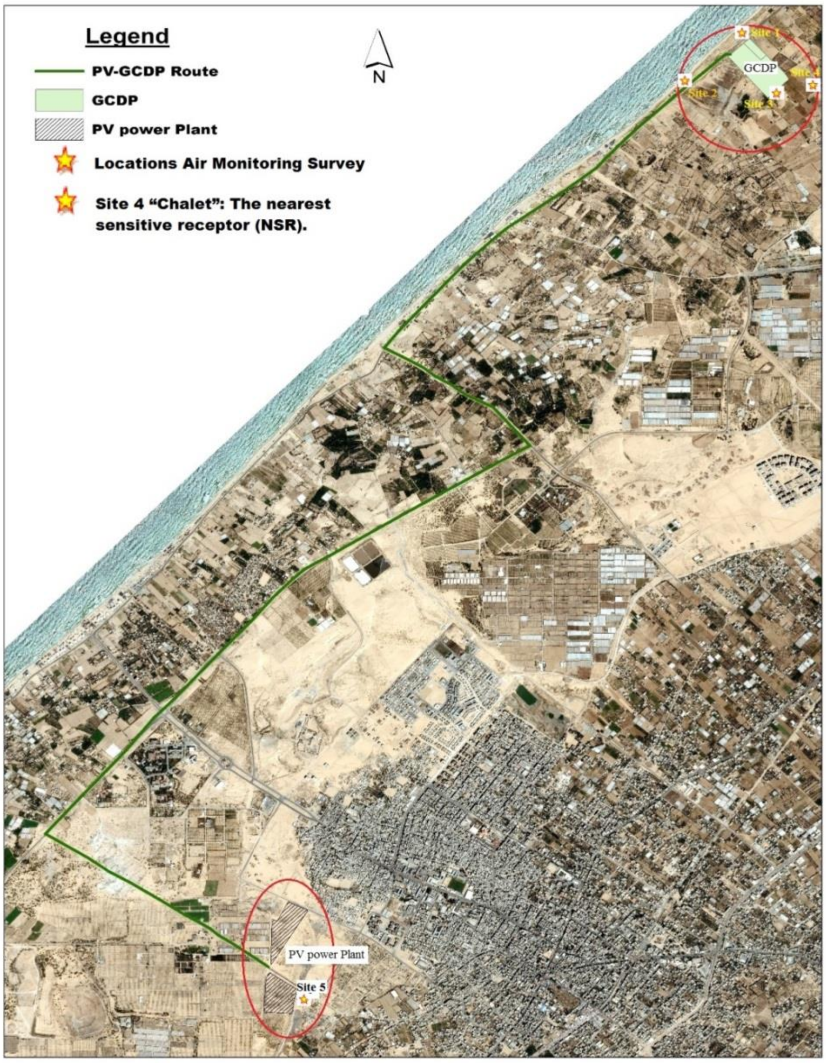


Figure 23: Air quality Monitoring Sites

Due to lack of information about the air quality levels in Gaza, a short term air quality monitoring survey for nitrogen dioxide (NO2), Sulphur dioxide (SO2), Carbon monoxide (CO), particles with a diameter less than 10 microns (PM10) and particles with a diameter less than 2.5 microns (PM2.5), have been carried out by the Environmental and rural research centre (EERC) – Islamic University of Gaza (IUG), to support the air quality assessment for this project, using HAL-HPC300 Handheld Laser Particle Counters measures particles suspended in the air in real time for measuring PM10.and PM2.5, and Handheld Multi gas Detector Model SKY2000-M4, use to measure CO, NO, NO2, for 10-15 min measurement each hour at height of 100-150 cm above the ground, at five appropriate positions at or near to the boundaries of the proposed GCDP and near the PV plant on ground structures, for (24 hour period) on Sunday to Monday 24 April and on Saturday to Sunday 21 May 2016, as shown in the Figures below.

The monitoring survey for nitrogen dioxide (NO2), Sulphur dioxide (SO2), Carbon monoxide (CO), (PM10) and (PM2.5), was undertaken at four "receptor pints or "sites" at the GCDP and surrounding area and one site at the Photovoltaic power plant (PV-PP), the monitoring survey was undertaken for a two day period on either 24.04.2016 or 21.05.2016 (hourly samples over one 24 hour cycle).

As described under each measurement position reported below, these positions were chosen for one or more of the following reasons:

1) Easily definable and with easy future access in case of need for comparison measurements during or after completion of the project.

2) Most likely to continue to exist after completion of the project.

3) Representative of the important background regimes.

Note 1: *It is important to know that the project main site STLV plant from UNICEF (currently under construction).*

The result of the air quality measurement in all five proposed sites (1, 2, 3, 4 and 5) shows that the average concentration of PM10 ranged between 46.7 to 847.5 ($\mu g/m^3$) and average concentration of PM2.5 ranged between 8.1 to 147.8 ($\mu g/m^3$).

Sites Description:

- **Site (1):** Directly located at the quayside Al Rasheed Street in the front site of GCDP, Al-Rasheed Street is one of the main roads in Gaza Srip linking the provinces of Rafah and Khan Younis with Gaza City and the north. During the measurements were taken, there were some construction activities of STLV plant from UNICEF and Sandstorm.
- **Site (2):** This location consider as reference site at the same quayside Al Rasheed Street is located to the south of the desalination plant is about 250 meters.
- **Site (3):** This site is located east of the GCDP, nearby is irregular farmhouse and field for military training.
- **Site (4):** This Site located near a seasonal residential building on the North-East side (Chalet) has been earlier defined as the nearest building from the GCDP. This seasonal residential building will not be considered as the nearest receptor point, since it is illegal building.
- **Site (5):** This site is an off-site power plant with PV plant on ground structures (separate site) from GCDP, located within Khan Younis area next to the municipal slaughterhouse near the mean road passing large and small vehicles, especially in the night hours where there are frequent traffic to the slaughterhouse.

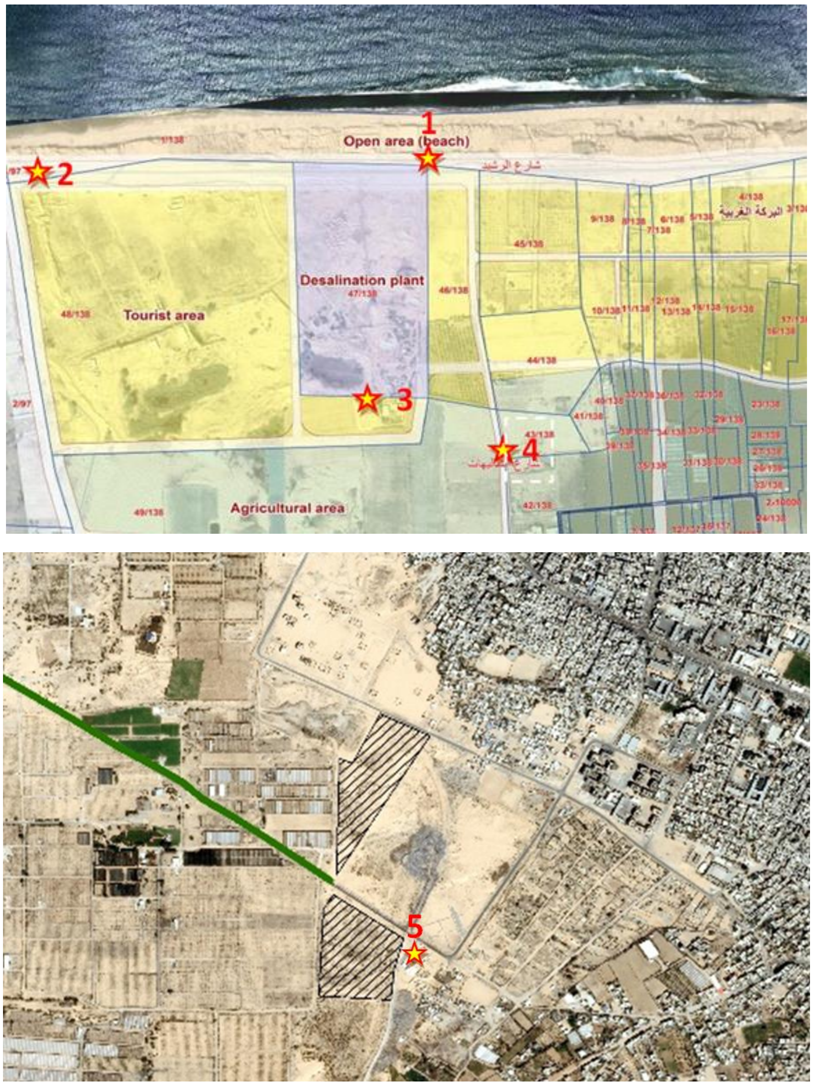


Figure 24: Air quality Monitoring Sites

The main results of the short-term air quality monitoring survey (one day each) carried out by (EERC) as follows:

NO2:

Location	date	Average(µg/m³)	Min	Max
Site 1	21.05.2016	4.2	BDL	14
Site 2	21.05.2016	2.6	BDL	6
Site 3	21.05.2016	BDL	BDL	BDL
Site 4 (Chalet)	21.05.2016	1	BDL	7
Site 5 (PV-PP)	21.05.2016	3.4	BDL	7

Table 5: NO2 (µg/m³)

SO2:

Location	date	Average (µg/m³)	Min (µg/m³)	Max (µg/m³)
Site 1	21.05.2016	1.95	BDL	4
Site 2	21.05.2016	1.30	BDL	2
Site 3	21.05.2016	BDL	BDL	BDL
Site 4 (Chalet)	21.05.2016	1	BDL	1
Site 5 (PV-PP)	21.05.2016	1.2	BDL	2

Table 6: SO2 (µg/m3)

CO:

Location	date	Average (mg/m³)	Min (mg/m³)	Max (µg/m³)
Site 1	21.05.2016	19.75	BDL	70
Site 2	21.05.2016	14.70	BDL	46
Site 3	21.05.2016	BDL	BDL	BDL
Site 4 (Chalet)	21.05.2016	13.5	BDL	25
Site 5 (PV-PP)	21.05.2016	16.3	BDL	35

Table 7: CO (mg/m3)

PM10:

Location	date	Average (µg/m³)	Min (µg/m³)	Max (µg/m³)
Site 1	24.04.2016	812.2	282	1402
Site 2	24.04.2016	847.5	113	1136
Site 3	24.04.2016	560.5	23	1092
Site 4 (Chalet)	24.04.2016	617.1	105	1148
Site 5 (PV-PP)	24.04.2016	46.7	2	107

Table 8: PM10 (µg/m3)

PM2.5:

Location	date	Average (µg/m³)	Min (µg/m³)	Max (µg/m³)
Site 1	24.04.2016	141.1	39	245
Site 2	24.04.2016	147.8	20	561
Site 3	24.04.2016	97.7	4	190
Site 4 (Chalet)	24.04.2016	107.4	17	199
Site 5 (PV-PP)	24.04.2016	8.1	0	19

Table 9: PM2.5 (µg/m3)

In general, values for NO_2, SO_2, and CO are well below their respective limit values (often below detection limits). Values for particulates (with the exception of Gaza City) exceed the limit values considerably, but due to the lack of local pyrogenic emission sources, these values are due to local "natural" dust, wind entrainment, **This is also obvious by the extreme short-term variations (more than a factor of 50 between hours) which is due to variable winds.**

Given their low values (NO_2, SO_2, CO) or their obviously "natural" yet local origin, the background values have no obvious bearing on the environmental impacts (or compliance) of the emission source. Also, it is important to realise that the data from one day (24 hours) have very little representative value given the considerable variability of the air quality parameters given the variable coastal winds.

As an example, consider the variability of the simulated NO_2 values at the receptor site No.4 (Chalet) located southeast of the GCDP defined as nearest sensitive receptor (NSR). Annual average for 2010 is 1.0, minimum 0, and the hourly maximum is 415.7. Picking an arbitrary day within the year can hardly be representative for that year, given the observed and simulated variability.

For particulates, the reported background maxima exceed anything that could be attributed to even large industrial sources – there are no major pyrogenic/anthropogenic emission source nearby, which clearly indicates "natural sources" which is local wind erosion of soils or long-range transport from the Sahara or the Arabian peninsula (see, for example: http://www.ess.co.at/LIFE). Values above 1,000 µg/m3 are certainly extreme and would represent SDS (Sand and dust storm) conditions which are certainly "natural". In comparison, the point source investigated is negligible.

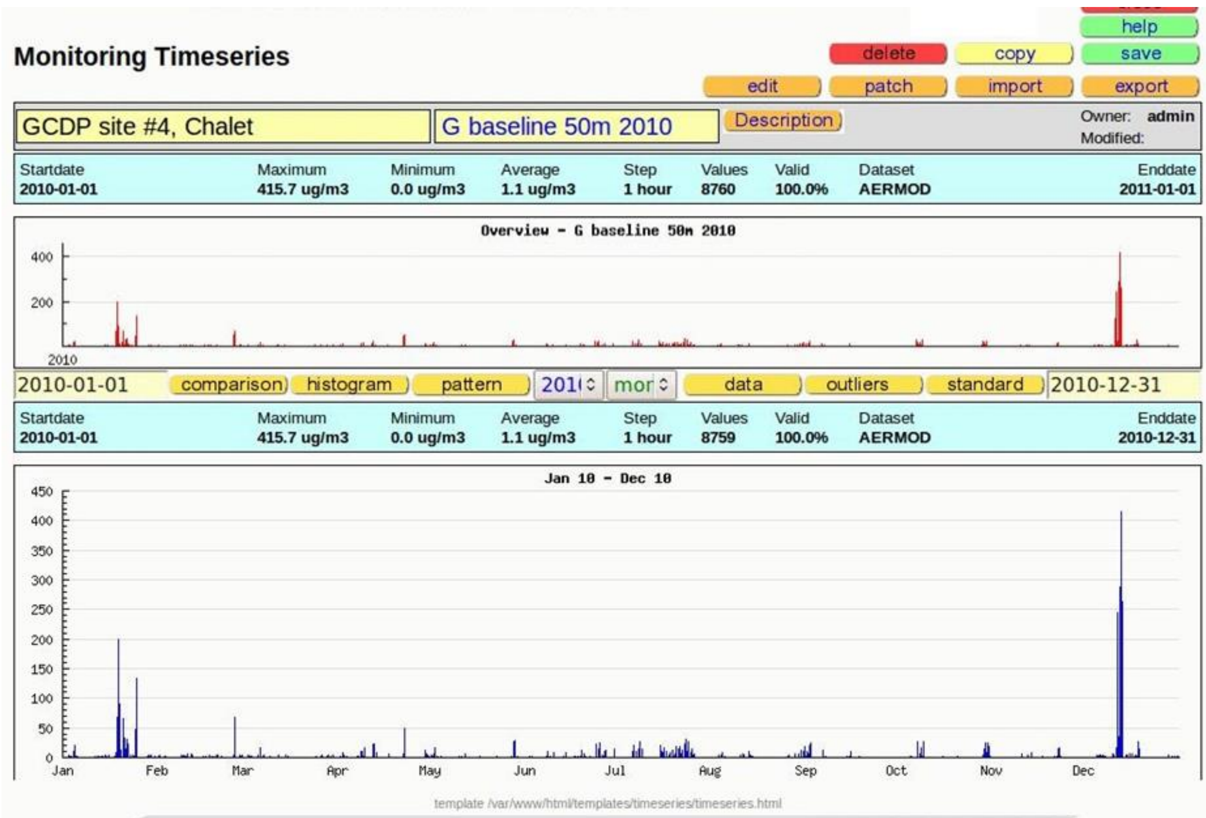


Figure 25: Annual time series, NOx, demonstrating variability (simulated)

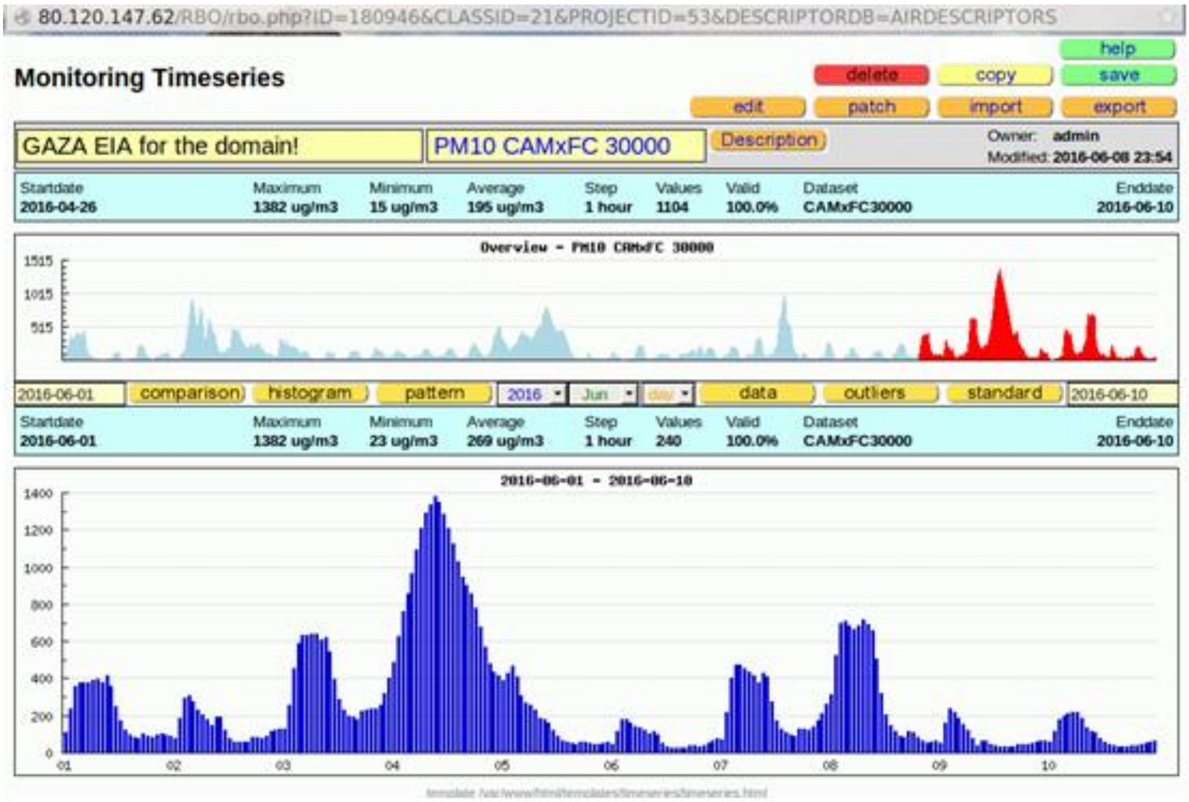


Figure 26: PM10 forecast results (CAMx) EIA domain center, showing short-term variability

10.1. Emission scenarios/values

The emission values (g/s) used are based on the EEA/EMEP emission factors (tier 2 estimates, see above) and source configuration:

Source configuration	NOx	SO2	PM10	CO
3 engines on diesel	33.40	11.0	0.50	8.90
2 engines on diesel + PV addition	22.27	7.3	0.33	5.93
3 engines on natural gas	2.00	0	0	0.90
2 engines on natural gas + PV addition	1.33	0	0	0.60

Table 10: EEA/EMEP emission factors

NFR code 1.A.1.a: Public electricity and heat production

- Diesel: large stationary reciprocating engines, gas oil, other liquid fuels
- Natural gas: natural gas (NG)

Please note that the SO2 emission estimates are adjusted (factor of 10) for a high sulfur content (quoted between 0,93 and of 0.093 %) versus the low-sulphur diesel standard of the EU (10 ppm under Euro5, 2009/30/EC).

10.2. Baseline scenarios

The baseline scenarios describe the most likely combination of emission data and evaluate this for the reference year 2014, and three additional years of meteorology, 2010, 2009, 2008 to also analyse the inter-annual variability of meteorological conditions and their effect on ambient pollutant concentrations.

NO2/NO

Maxima and minima marked RED and GREEN,

Year	Avg µg/m³	Max (a) µg/m³	Max (h) µg/m³	N.ex (h)	% hours	% locations
2014	2.26	12.2	354	0 (2)	0	0
2010	0.445	2.26	582	>30	0.091	>0.3
2009	0.514	2.71	429	3	0.004	0.03
2008	0.554	2.82	423	1	0.011	0.01

Table 11: NO2/NOx (µg/m3)

*Please note: due to their dependency on the arbitrary domain size and "resolution", annual average, total number of violations, and the % values are only meaningful for scenario comparison. For 2010, exceedances are observed at 8 different hours (from a total of 365*24 hours simulated, and all at closely at neighbouring locations) but all within two days, 2010 12 11 and 2010 12 12. During all these events, the meteorological pre-processor failed for PBL computations. 2014 would indicate two violations against EU standards, none against national standards.*

Air quality reference/limit values for NO_2 in µg/m³:

Aggregation period	National	EU
1 hour	400	200
Annual average	100	40

Table 12: Air quality reference/limit values for NO2 (µg/m3)

NOTE: the EU regulation allows up to 18 annual exceedances (hourly).

Avg µg/m³	annual average over the domain
max(a) µg/m³	annual maxima within the domain (receptor grid cells)
max(h) µg/m³	hourly maxima
N.ex (h)	number of hourly exceedances in the domain
% hours	% of the hours (from 8,760) when exceedance was predicted
% locations	% of grid cells where exceedance was predicted

NO2 Compliance at the sensitive receptor location "Chalet":

Year	Annual average (µg/m³)	Hourly max. (µg/m³)	N. exceedances (considering National Standards)
2014	1.2	326.6	0
2010	1.1	415.7	6
2009	1.8	312.9	0
2008	1.1	372.4	0

Table 13: NO2 Compliance at the sensitive receptor location "Chalet" (µg/m3)

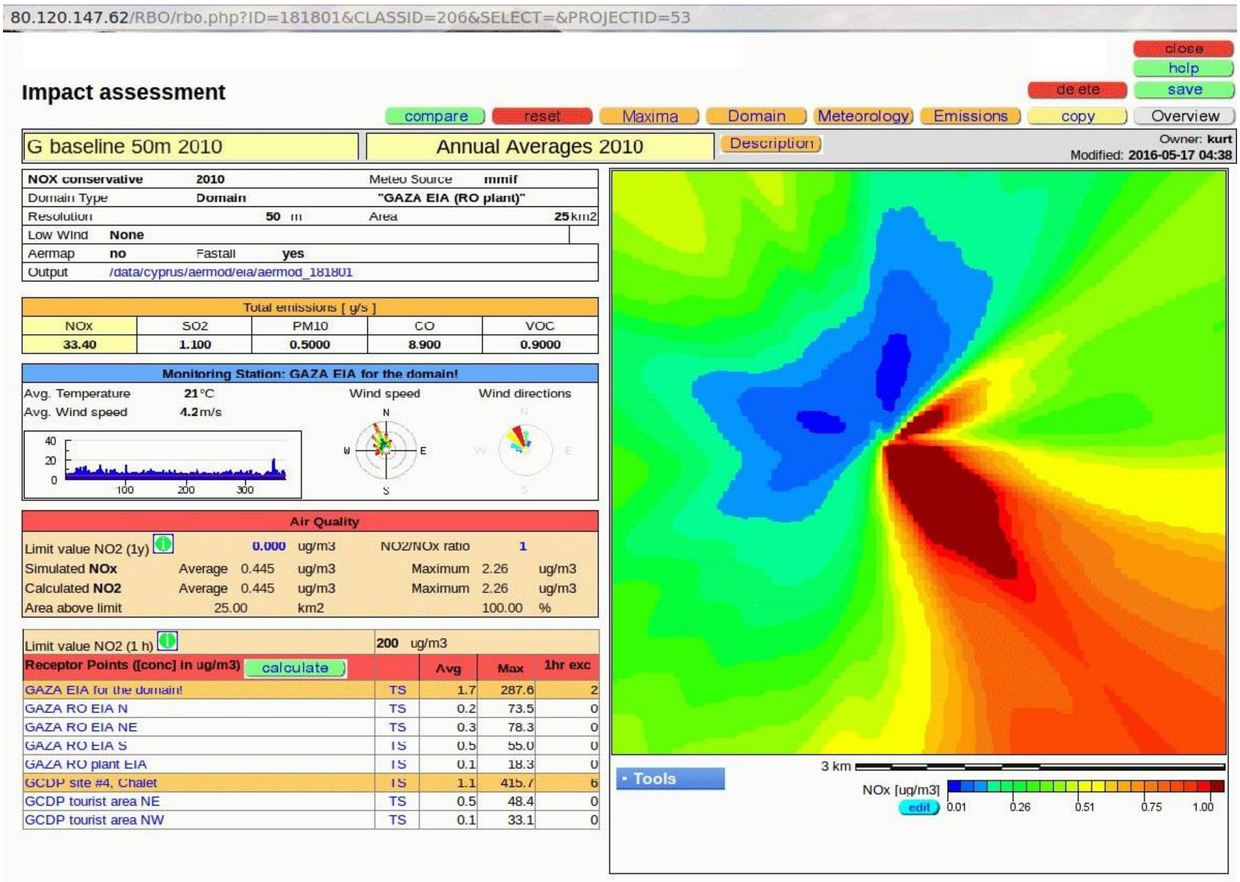
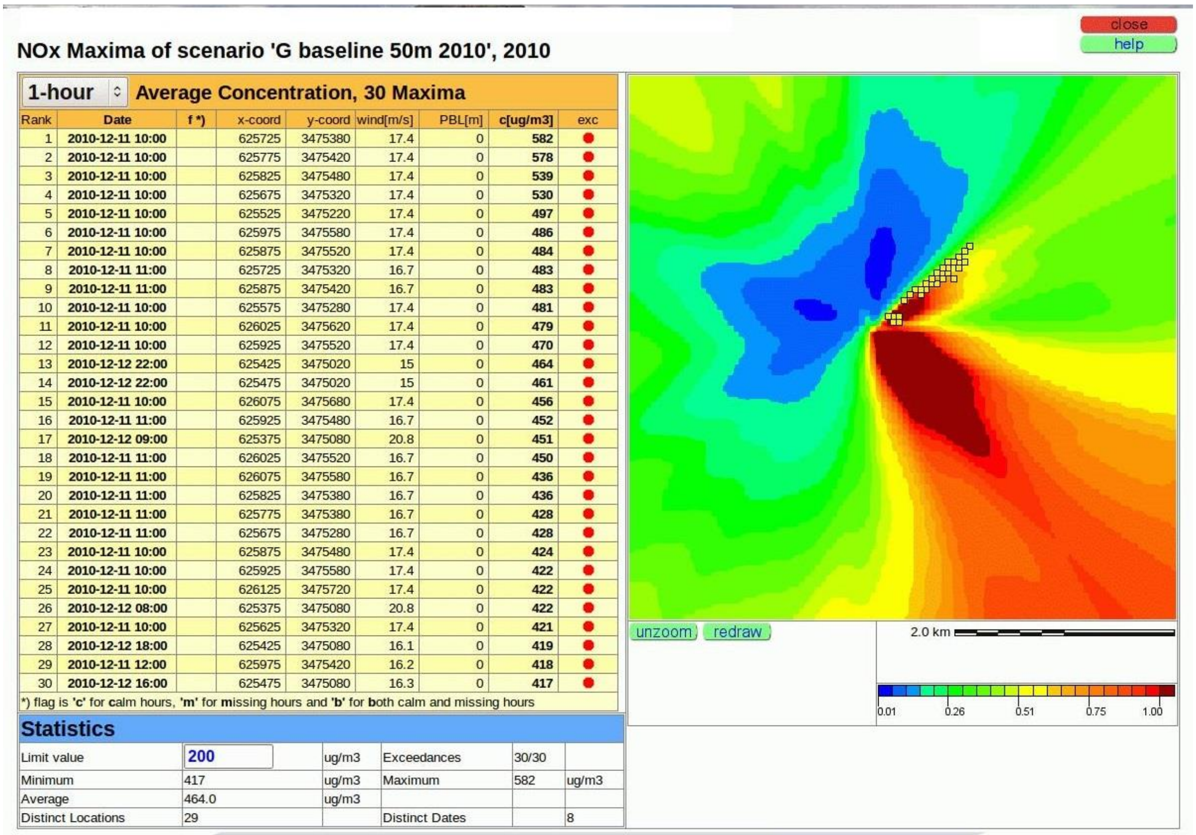


Figure 27: Baseline, 3 engines diesel, annual average



NOx Maxima of scenario 'G baseline 50m 2010', 2010

1-hour Average Concentration, 30 Maxima

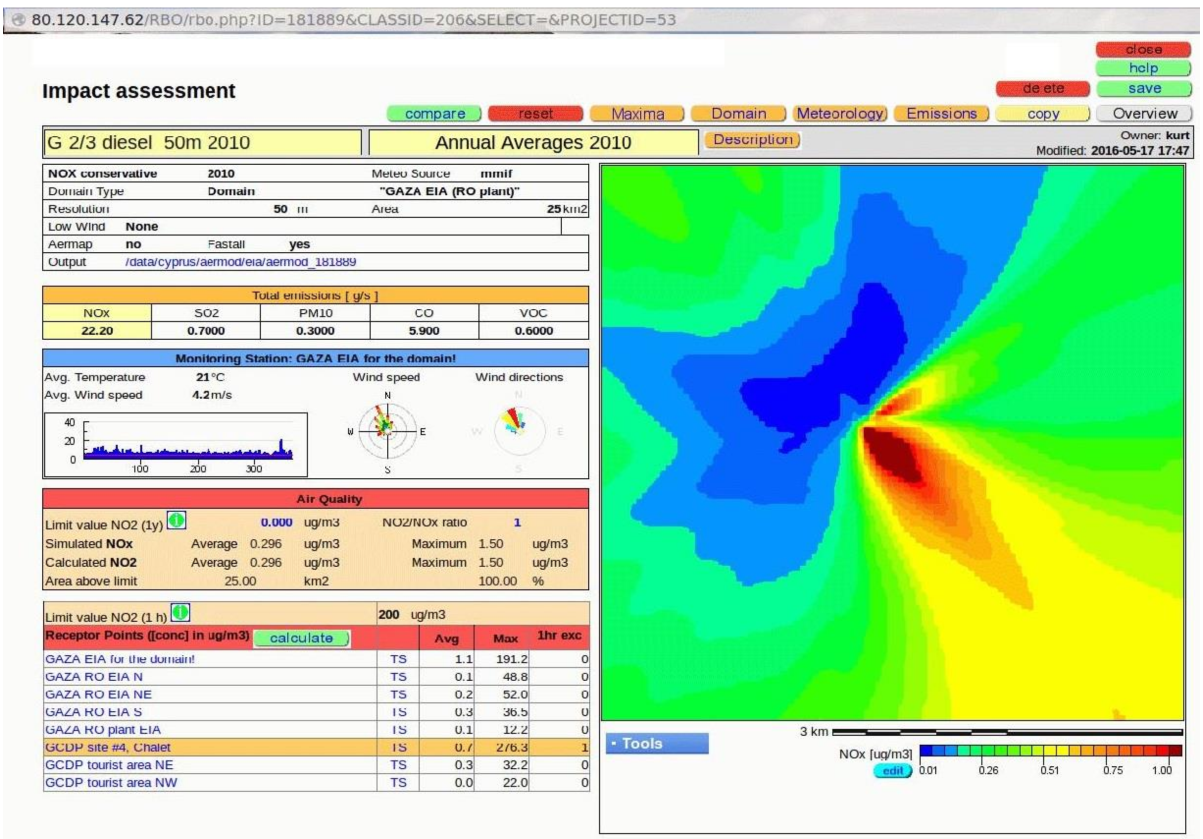
Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-11 10:00		625725	3475380	17.4	0	582	●
2	2010-12-11 10:00		625775	3475420	17.4	0	578	●
3	2010-12-11 10:00		625825	3475480	17.4	0	539	●
4	2010-12-11 10:00		625675	3475320	17.4	0	530	●
5	2010-12-11 10:00		625525	3475220	17.4	0	497	●
6	2010-12-11 10:00		625975	3475580	17.4	0	486	●
7	2010-12-11 10:00		625875	3475520	17.4	0	484	●
8	2010-12-11 11:00		625725	3475320	16.7	0	483	●
9	2010-12-11 11:00		625875	3475420	16.7	0	483	●
10	2010-12-11 10:00		625575	3475280	17.4	0	481	●
11	2010-12-11 10:00		626025	3475620	17.4	0	479	●
12	2010-12-11 10:00		625925	3475520	17.4	0	470	●
13	2010-12-12 22:00		625425	3475020	15	0	464	●
14	2010-12-12 22:00		625475	3475020	15	0	461	●
15	2010-12-11 10:00		626075	3475680	17.4	0	456	●
16	2010-12-11 11:00		625925	3475480	16.7	0	452	●
17	2010-12-12 09:00		625375	3475080	20.8	0	451	●
18	2010-12-11 11:00		626025	3475520	16.7	0	450	●
19	2010-12-11 11:00		626075	3475580	16.7	0	436	●
20	2010-12-11 11:00		625825	3475380	16.7	0	436	●
21	2010-12-11 11:00		625775	3475380	16.7	0	428	●
22	2010-12-11 11:00		625675	3475280	16.7	0	428	●
23	2010-12-11 10:00		625875	3475480	17.4	0	424	●
24	2010-12-11 10:00		625925	3475580	17.4	0	422	●
25	2010-12-11 10:00		626125	3475720	17.4	0	422	●
26	2010-12-12 08:00		625375	3475080	20.8	0	422	●
27	2010-12-11 10:00		625625	3475320	17.4	0	421	●
28	2010-12-12 18:00		625425	3475080	16.1	0	419	●
29	2010-12-11 12:00		625975	3475420	16.2	0	418	●
30	2010-12-12 16:00		625475	3475080	16.3	0	417	●

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	200	ug/m3	Exceedances	30/30	
Minimum	417	ug/m3	Maximum	582	ug/m3
Average	464.0	ug/m3			
Distinct Locations	29		Distinct Dates		8

Figure 28: Baseline, 3 diesel engines, hourly maxima/locations



Impact assessment

G 2/3 diesel 50m 2010 | Annual Averages 2010

NOX conservative	2010	Meteo Source	mmif
Domain Type	Domain	"GAZA EIA (RO plant)"	
Resolution	50 m	Area	25 km2
Low Wind	None		
Aermap no	Fastall yes		
Output	/data/cyprus/aermod/eia/aermod_181889		

Total emissions [g/s]

NOx	SO2	PM10	CO	VOC
22.20	0.7000	0.3000	5.900	0.6000

Monitoring Station: GAZA EIA for the domain!

Avg. Temperature 21 °C
Avg. Wind speed 4.2 m/s
Wind speed | Wind directions

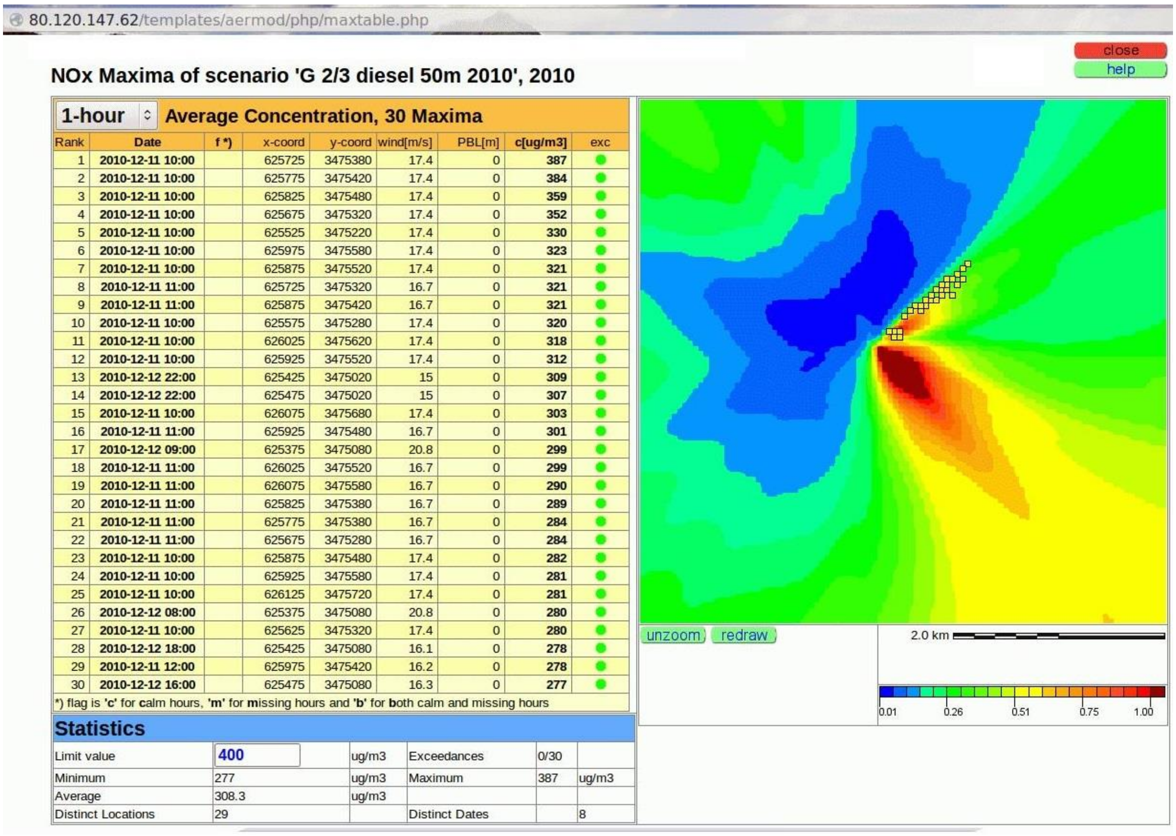
Air Quality

Limit value NO2 (1y)		0.000	ug/m3	NO2/NOx ratio	1	
Simulated NOx	Average	0.296	ug/m3	Maximum	1.50	ug/m3
Calculated NO2	Average	0.296	ug/m3	Maximum	1.50	ug/m3
Area above limit		25.00	km2		100.00	%

Limit value NO2 (1 h) 200 ug/m3

Receptor Points ([conc] in ug/m3)		Avg	Max	1hr exc
GAZA EIA for the domain!	TS	1.1	191.2	0
GAZA RO EIA N	TS	0.1	48.8	0
GAZA RO EIA NE	TS	0.2	52.0	0
GAZA RO EIA S	TS	0.3	36.5	0
GAZA RO plant EIA	TS	0.1	12.2	0
GCDP site #4, Chalet	TS	0.7	276.3	1
GCDP tourist area NE	TS	0.3	32.2	0
GCDP tourist area NW	TS	0.0	22.0	0

Figure 29: 2 diesel engines (+PV)



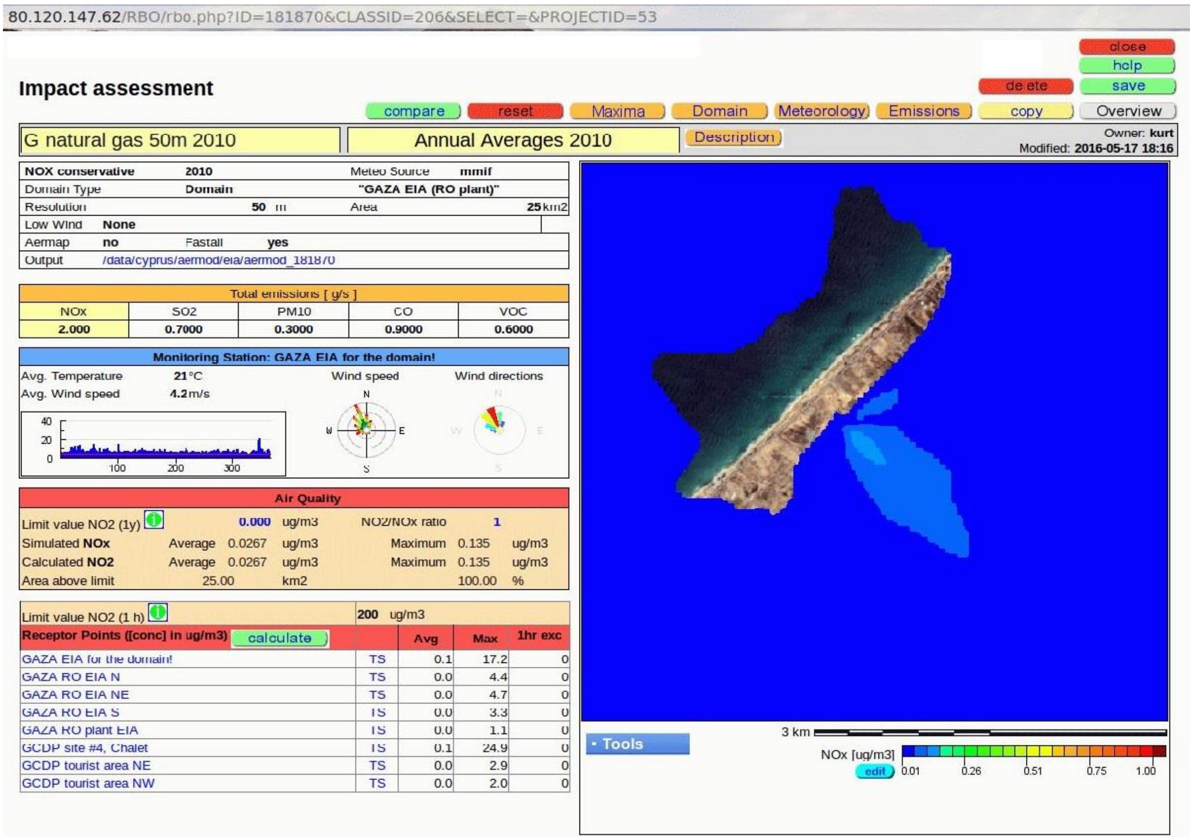
Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-11 10:00		625725	3475380	17.4	0	387	
2	2010-12-11 10:00		625775	3475420	17.4	0	384	
3	2010-12-11 10:00		625825	3475480	17.4	0	359	
4	2010-12-11 10:00		625675	3475320	17.4	0	352	
5	2010-12-11 10:00		625525	3475220	17.4	0	330	
6	2010-12-11 10:00		625975	3475580	17.4	0	323	
7	2010-12-11 10:00		625875	3475520	17.4	0	321	
8	2010-12-11 11:00		625725	3475320	16.7	0	321	
9	2010-12-11 11:00		625875	3475420	16.7	0	321	
10	2010-12-11 10:00		625575	3475280	17.4	0	320	
11	2010-12-11 10:00		626025	3475620	17.4	0	318	
12	2010-12-11 10:00		625925	3475520	17.4	0	312	
13	2010-12-12 22:00		625425	3475020	15	0	309	
14	2010-12-12 22:00		625475	3475020	15	0	307	
15	2010-12-11 10:00		626075	3475680	17.4	0	303	
16	2010-12-11 11:00		625925	3475480	16.7	0	301	
17	2010-12-12 09:00		625375	3475080	20.8	0	299	
18	2010-12-11 11:00		626025	3475520	16.7	0	299	
19	2010-12-11 11:00		626075	3475580	16.7	0	290	
20	2010-12-11 11:00		625825	3475380	16.7	0	289	
21	2010-12-11 11:00		625775	3475380	16.7	0	284	
22	2010-12-11 11:00		625675	3475280	16.7	0	284	
23	2010-12-11 10:00		625875	3475480	17.4	0	282	
24	2010-12-11 10:00		625925	3475580	17.4	0	281	
25	2010-12-11 10:00		626125	3475720	17.4	0	281	
26	2010-12-12 08:00		625375	3475080	20.8	0	280	
27	2010-12-11 10:00		625625	3475320	17.4	0	280	
28	2010-12-12 18:00		625425	3475080	16.1	0	278	
29	2010-12-11 12:00		625975	3475420	16.2	0	278	
30	2010-12-12 16:00		625475	3475080	16.3	0	277	

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	400	ug/m3	Exceedances	0/30	
Minimum	277	ug/m3	Maximum	387	ug/m3
Average	308.3	ug/m3			
Distinct Locations	29		Distinct Dates		8

Figure 30: 2 diesel engines (+ PV), maxima, locations



NOX conservative	2010	Meteo Source	mmif
Domain Type	Domain	"GAZA EIA (RO plant)"	
Resolution	50 m	Area	25 km2
Low Wind	None		
Aermap	no	Fastall	yes
Output	/data/cyprus/aermod/eia/aermod_181870		

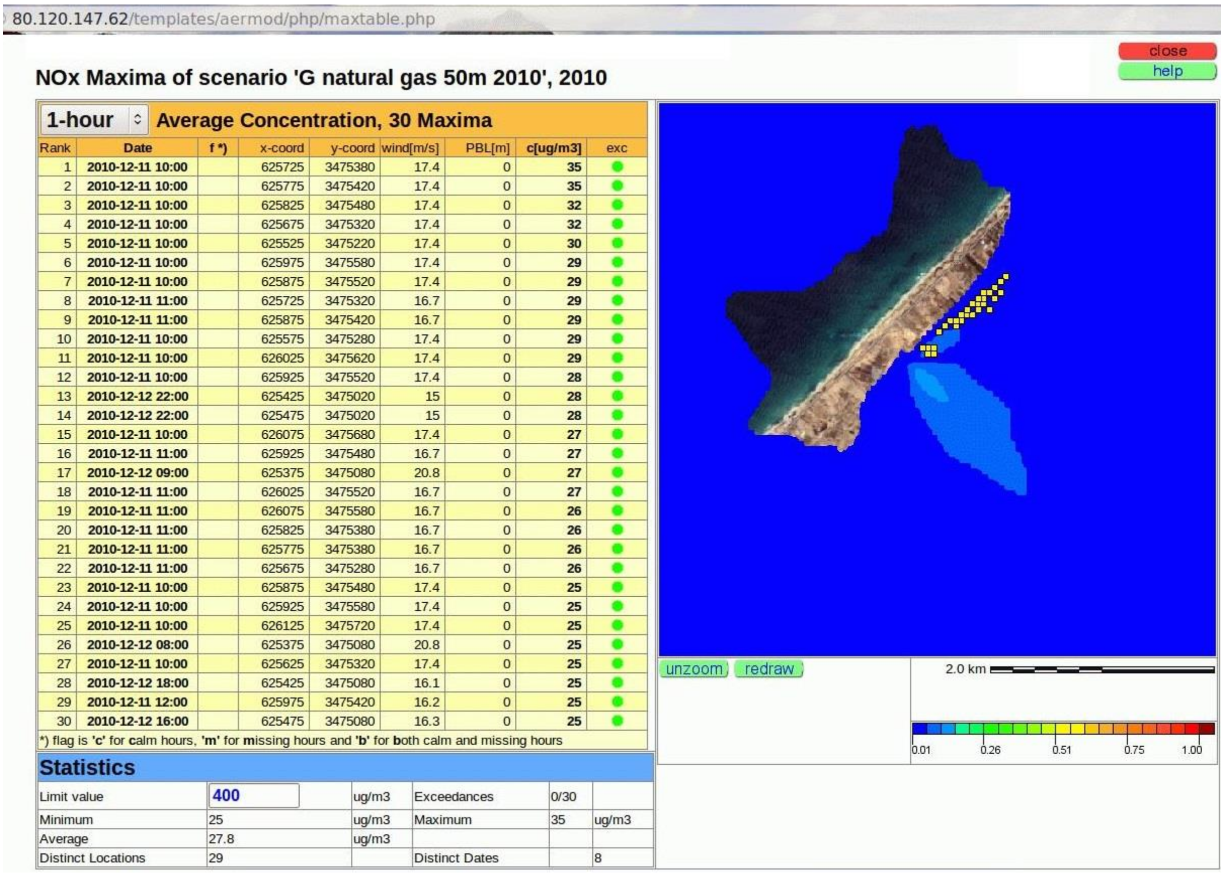
Total emissions [g/s]				
NOx	SO2	PM10	CO	VOC
2.000	0.7000	0.3000	0.9000	0.6000

Air Quality						
Limit value NO2 (1y)		0.000	ug/m3	NO2/NOx ratio	1	
Simulated NOx	Average	0.0267	ug/m3	Maximum	0.135	ug/m3
Calculated NO2	Average	0.0267	ug/m3	Maximum	0.135	ug/m3
Area above limit		25.00	km2		100.00	%

Limit value NO2 (1 h) 200 ug/m3

Receptor Points ([conc] in ug/m3)		Avg	Max	1hr exc
GAZA EIA for the domain!	TS	0.1	17.2	0
GAZA RO EIA N	TS	0.0	4.4	0
GAZA RO EIA NE	TS	0.0	4.7	0
GAZA RO EIA S	TS	0.0	3.3	0
GAZA RO plant EIA	TS	0.0	1.1	0
GCDP site #4, Chalet	TS	0.1	24.9	0
GCDP tourist area NE	TS	0.0	2.9	0
GCDP tourist area NW	TS	0.0	2.0	0

Figure 31: 3 engines, natural gas



Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-11 10:00		625725	3475380	17.4	0	35	
2	2010-12-11 10:00		625775	3475420	17.4	0	35	
3	2010-12-11 10:00		625825	3475480	17.4	0	32	
4	2010-12-11 10:00		625675	3475320	17.4	0	32	
5	2010-12-11 10:00		625525	3475220	17.4	0	30	
6	2010-12-11 10:00		625975	3475580	17.4	0	29	
7	2010-12-11 10:00		625875	3475520	17.4	0	29	
8	2010-12-11 11:00		625725	3475320	16.7	0	29	
9	2010-12-11 11:00		625875	3475420	16.7	0	29	
10	2010-12-11 10:00		625575	3475280	17.4	0	29	
11	2010-12-11 10:00		626025	3475620	17.4	0	29	
12	2010-12-11 10:00		625925	3475520	17.4	0	28	
13	2010-12-12 22:00		625425	3475020	15	0	28	
14	2010-12-12 22:00		625475	3475020	15	0	28	
15	2010-12-11 10:00		626075	3475680	17.4	0	27	
16	2010-12-11 11:00		625925	3475480	16.7	0	27	
17	2010-12-12 09:00		625375	3475080	20.8	0	27	
18	2010-12-11 11:00		626025	3475520	16.7	0	27	
19	2010-12-11 11:00		626075	3475580	16.7	0	26	
20	2010-12-11 11:00		625825	3475380	16.7	0	26	
21	2010-12-11 11:00		625775	3475380	16.7	0	26	
22	2010-12-11 11:00		625675	3475280	16.7	0	26	
23	2010-12-11 10:00		625875	3475480	17.4	0	25	
24	2010-12-11 10:00		625925	3475580	17.4	0	25	
25	2010-12-11 10:00		626125	3475720	17.4	0	25	
26	2010-12-12 08:00		625375	3475080	20.8	0	25	
27	2010-12-11 10:00		625625	3475320	17.4	0	25	
28	2010-12-12 18:00		625425	3475080	16.1	0	25	
29	2010-12-11 12:00		625975	3475420	16.2	0	25	
30	2010-12-12 16:00		625475	3475080	16.3	0	25	

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	400	ug/m3	Exceedances	0/30	
Minimum	25	ug/m3	Maximum	35	ug/m3
Average	27.8	ug/m3			
Distinct Locations	29		Distinct Dates		8

Figure 32: 3 engines, natural gas, maxima, locations

SO2:

Based on the worst case emission scenarios (3 diesel engines) and the worst case meteorology (2010), the simulations show full compliance (National and international standards), and yield:

Year	Max(1 hour) μg/m^3	Max(24 hours) μg/m^3
2014	117	39
2010	192	67

Table 14: SO2 Compliance (μg/m3)

Applicable national standard: 250 μg/m^3 (24 hours); EU: 350μg/m^3 (1 hour), with up to 38 permitted exceedances (if any) each year. 125 μg/m^3 (24 hours) 3 permitted annual exceedances;

80.120.147.62/templates/aermod/php/maxtable.php?scenarioID=181972&PROJECTID=53

close
help

SO2 Maxima of scenario 'G SO2 baseline 50m 2010', 2010

1-hour — Average Concentration, 30 Maxima

Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-11 10:00		625725	3475380	17.4	0	192	
2	2010-12-11 10:00		625775	3475420	17.4	0	190	
3	2010-12-11 10:00		625825	3475480	17.4	0	178	
4	2010-12-11 10:00		625675	3475320	17.4	0	175	
5	2010-12-11 10:00		625525	3475220	17.4	0	164	
6	2010-12-11 10:00		625975	3475580	17.4	0	160	
7	2010-12-11 10:00		625875	3475520	17.4	0	159	
8	2010-12-11 11:00		625725	3475320	16.7	0	159	
9	2010-12-11 11:00		625875	3475420	16.7	0	159	
10	2010-12-11 10:00		625575	3475280	17.4	0	158	
11	2010-12-11 10:00		626025	3475620	17.4	0	158	
12	2010-12-11 10:00		625925	3475520	17.4	0	155	
13	2010-12-12 22:00		625425	3475020	15	0	153	
14	2010-12-12 22:00		625475	3475020	15	0	152	
15	2010-12-11 10:00		626075	3475680	17.4	0	150	
16	2010-12-11 11:00		625925	3475480	16.7	0	149	
17	2010-12-12 09:00		625375	3475080	20.8	0	148	
18	2010-12-11 11:00		626025	3475520	16.7	0	148	
19	2010-12-11 11:00		626075	3475580	16.7	0	144	
20	2010-12-11 11:00		625825	3475380	16.7	0	143	
21	2010-12-11 11:00		625775	3475380	16.7	0	141	
22	2010-12-11 11:00		625675	3475280	16.7	0	141	
23	2010-12-11 10:00		625875	3475480	17.4	0	140	
24	2010-12-11 10:00		625925	3475580	17.4	0	139	
25	2010-12-11 10:00		626125	3475720	17.4	0	139	
26	2010-12-12 08:00		625375	3475080	20.8	0	139	
27	2010-12-11 10:00		625625	3475320	17.4	0	139	
28	2010-12-12 18:00		625425	3475080	16.1	0	138	
29	2010-12-11 12:00		625975	3475420	16.2	0	138	
30	2010-12-12 16:00		625475	3475080	16.3	0	137	

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	350	ug/m3	Exceedances	0/30	
Minimum	137	ug/m3	Maximum	192	ug/m3
Average	152.8	ug/m3			
Distinct Locations	29		Distinct Dates		8

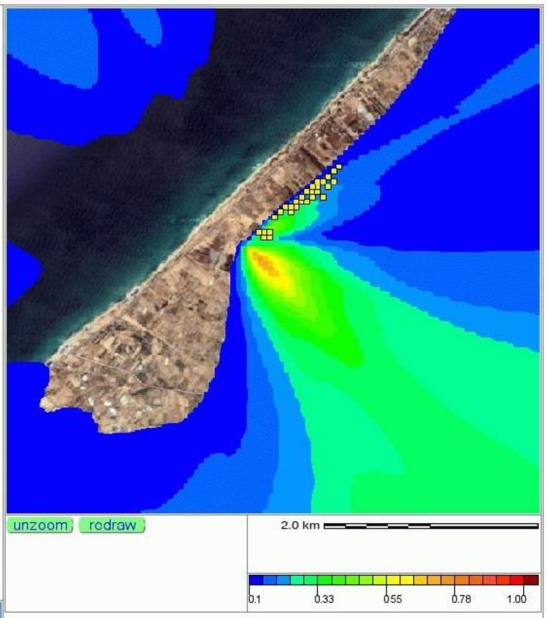


Figure 33: SO2, hourly compliance (EU standard)

close
help

SO2 Maxima of scenario 'G SO2 baseline 50m 2010', 2010

24-hour — Average Concentration, 30 Maxima

Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-12 24:00		625375	3475080	-		67	
2	2010-12-12 24:00		625475	3475120	-		64	
3	2010-12-12 24:00		625425	3475120	-		61	
4	2010-12-12 24:00		625425	3475080	-		61	
5	2010-12-12 24:00		625525	3475180	-		54	
6	2010-12-12 24:00		625525	3475120	-		49	
7	2010-12-12 24:00		625475	3475180	-		48	
8	2010-12-12 24:00		625575	3475180	-		47	
9	2010-12-12 24:00		625575	3475220	-		44	
10	2010-12-11 24:00		625475	3475120	-		42	
11	2010-12-11 24:00		625425	3475080	-		41	
12	2010-12-12 24:00		625625	3475220	-		41	
13	2010-12-12 24:00		625475	3475080	-		39	
14	2010-12-11 24:00		625575	3475180	-		38	
15	2010-12-11 24:00		625525	3475120	-		37	
16	2010-12-12 24:00		625625	3475180	-		36	
17	2010-12-12 24:00		625525	3475220	-		36	
18	2010-12-12 24:00		625625	3475280	-		35	
19	2010-12-11 24:00		625525	3475180	-		34	
20	2010-12-12 24:00		625675	3475280	-		34	
21	2010-12-12 24:00		625675	3475220	-		34	
22	2010-12-12 24:00		625575	3475120	-		34	
23	2010-12-12 24:00		625325	3475020	-		33	
24	2010-12-11 24:00		625625	3475220	-		33	
25	2010-12-11 24:00		625675	3475220	-		31	
26	2010-12-12 24:00		625725	3475280	-		30	
27	2010-12-11 24:00		625625	3475180	-		30	
28	2010-12-11 24:00		625375	3475080	-		29	
29	2010-12-11 24:00		625725	3475280	-		29	
30	2010-12-12 24:00		625725	3475320	-		29	

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	250	ug/m3	Exceedances	0/30	
Minimum	29	ug/m3	Maximum	67	ug/m3
Average	40.7	ug/m3			
Distinct Locations	20		Distinct Dates		2

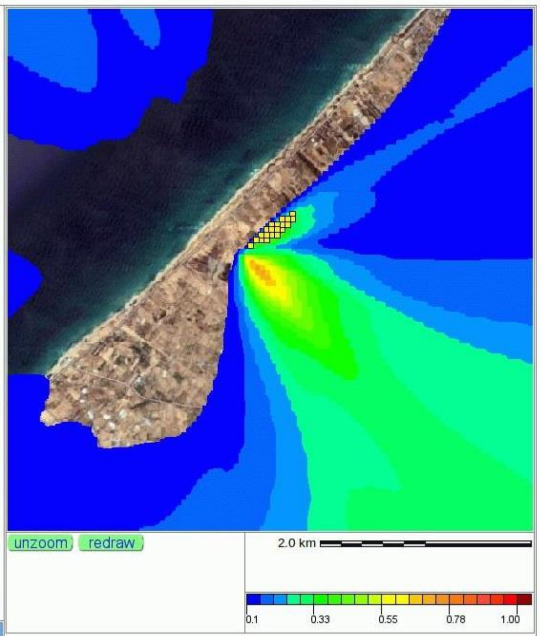


Figure 34: SO2, 24 hour compliance (national standard)

Compliance at sensitive receptor point "Chalet":

Year	Annual average ($\mu g/m^3$)	Hourly max. ($\mu g/m^3$)	N. exceedances	compliance
2010	0.3	136.9	0	
2014	0.4	106.6	0	

Table 15: SO2 Compliance at the sensitive receptor location "Chalet" (µg/m3)

24 hour values:

Maximum 2010; 24.94 $\mu g/m^3$
Maximum 2014: 24.50 $\mu g/m^3$

PM10:

Applicable national standard: 150 $\mu g/m^3$ (24 hours); 70 $\mu g/m^3$ (annual);EU: 50 $\mu g/m^3$ (24 hours), 40 $\mu g/m^3$ (annual).

PM10/2.5 compliance, domain in $\mu g/m^3$

Year	Annual average ($\mu g/m^3$)	Daily max. ($\mu g/m^3$)	N. exceedances	compliance
2010	0.007	3.0	0	
2014	0.0034	2.0	0	

Table 16: PM10/2.5 compliance (µg/m3)

PM10/2.5 compliance at sensitive receptor point "Chalet" in µg/m3

Year	Annual average ($\mu g/m^3$	Daily max. ($\mu g/m^3$	N. exceedances	compliance
2010	0.007	5.1	0	
2014	0.034	1.12	0	

Table 17: PM10/2.5 compliance at sensitive receptor point "Chalet" (µg/m3)

Annual average is orders of magnitude below the limit value.
Since the PM10 values are in compliance with the annual average PM2.5 limit PM2.5 as a component of PM10, **PM2.5 is in compliance as well.**

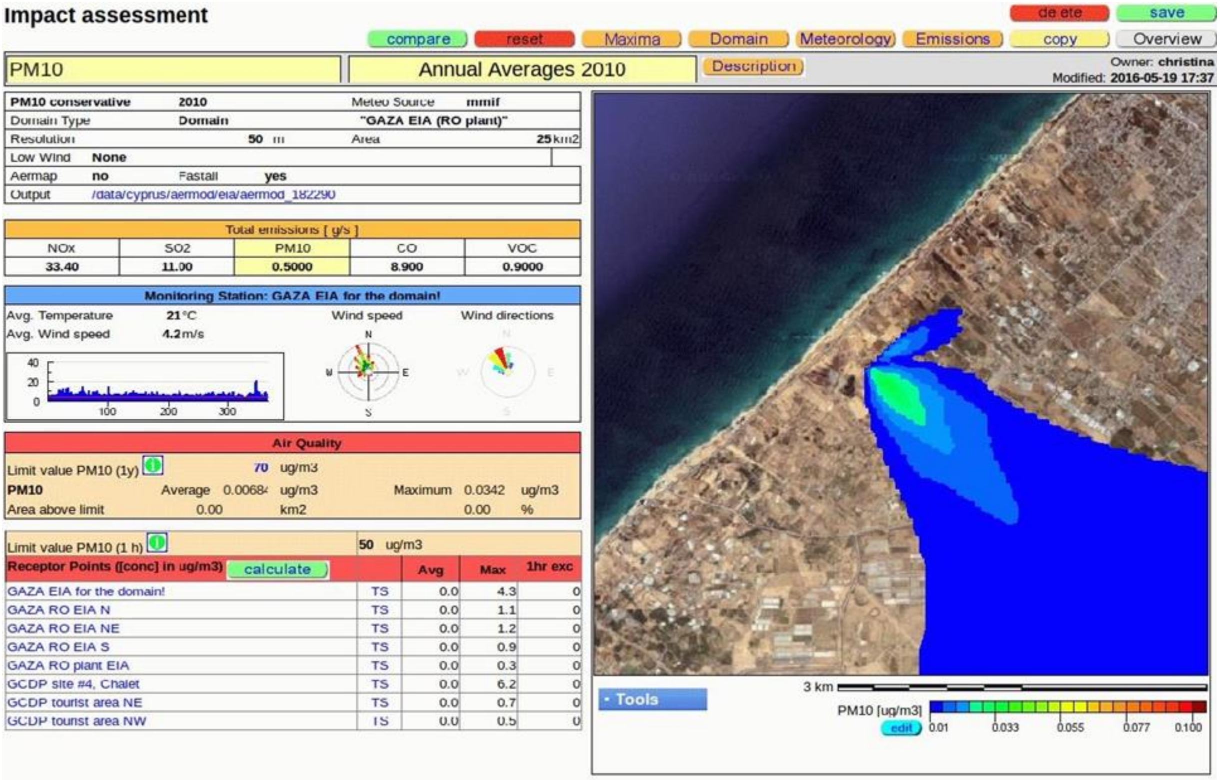


Figure 35: PM10, annual average

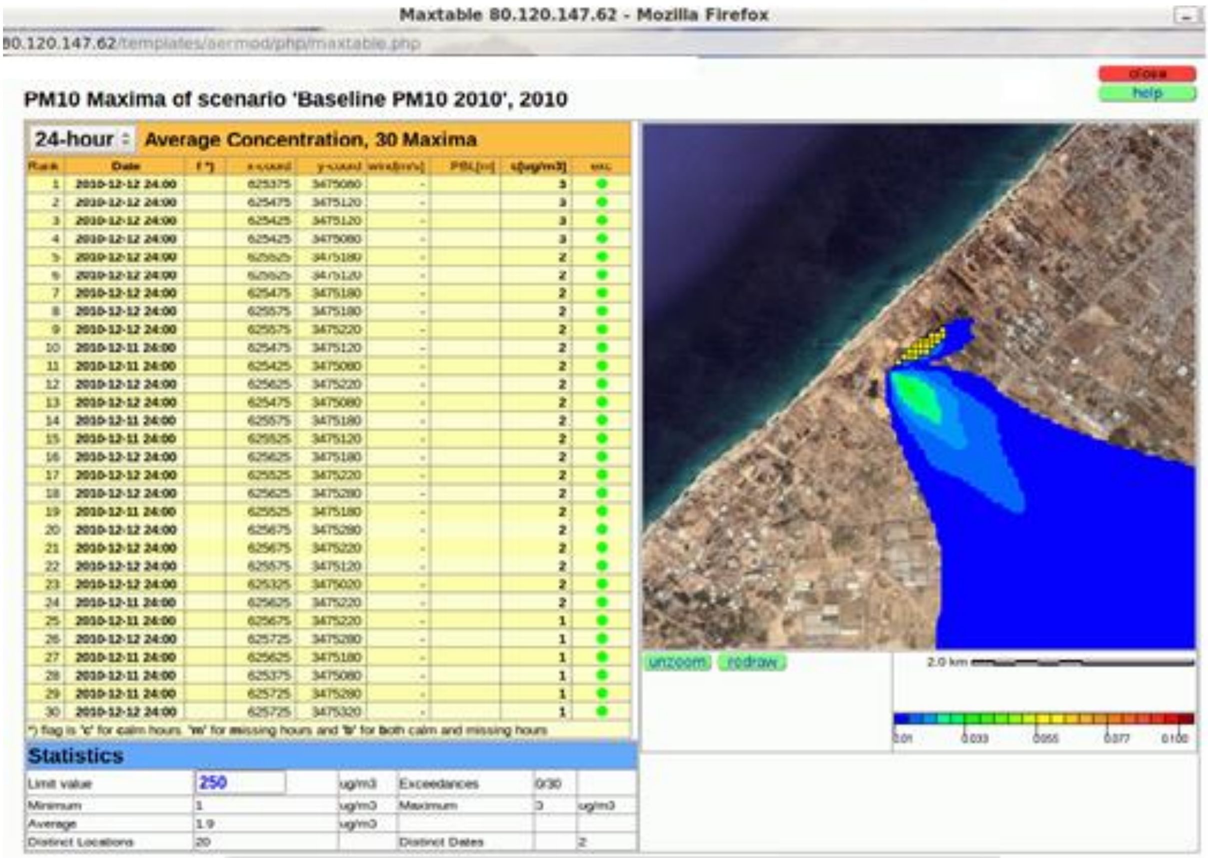


Figure 36: PM10, 24 hrs maxima (compliance with national standard)

CO:

Diesel engines operate with excess air, so that little or no CO gets emitted.

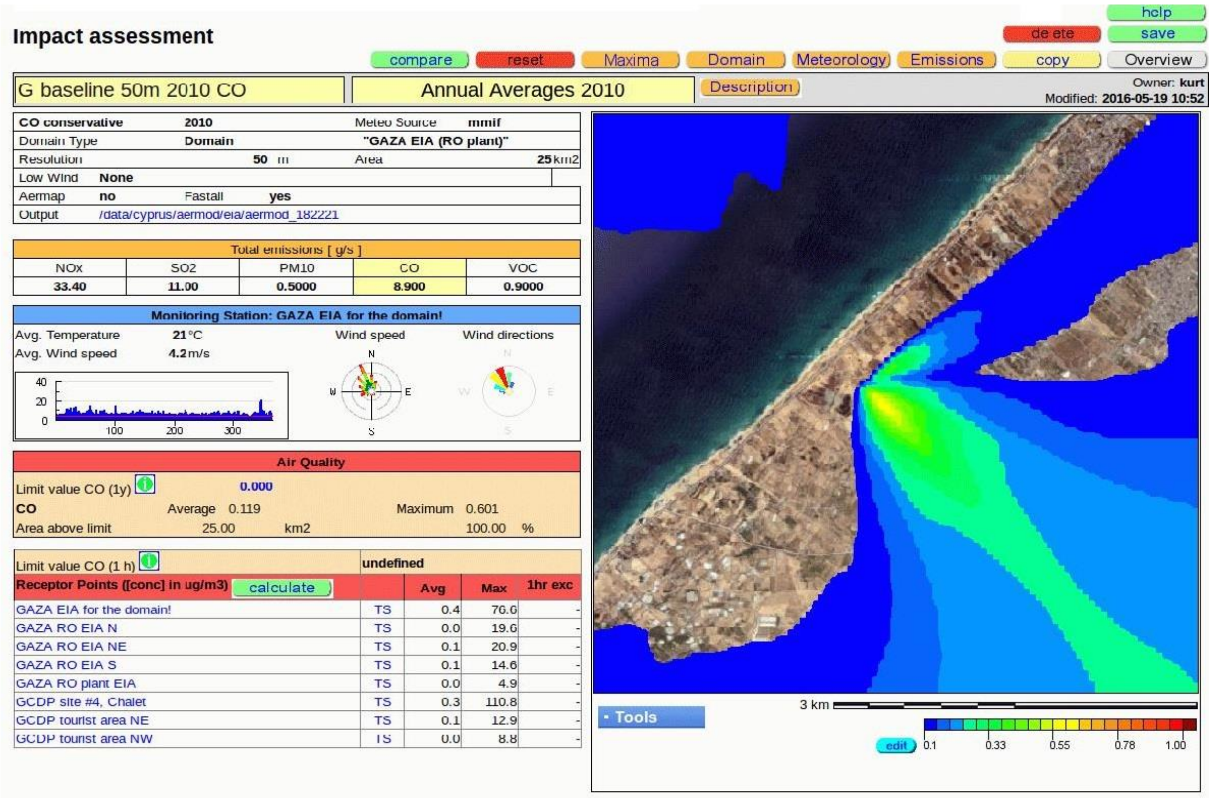


Figure 37: CO, annual averages

CO compliance at sensitive receptor point “Chalet” (in µg/m3)

Year	Annual average (µg/m³)	Hourly max. (µg/m³)	N. exceedances	compliance
2010	0.3	110.8	0	
2014	0.6	94.0	0	

Table 18: CO compliance at sensitive receptor point “Chalet” (µg/m3)

Since the hourly maximum value is almost two orders of magnitude below the 8 hours average limit value, the **CO compliance is guaranteed.**

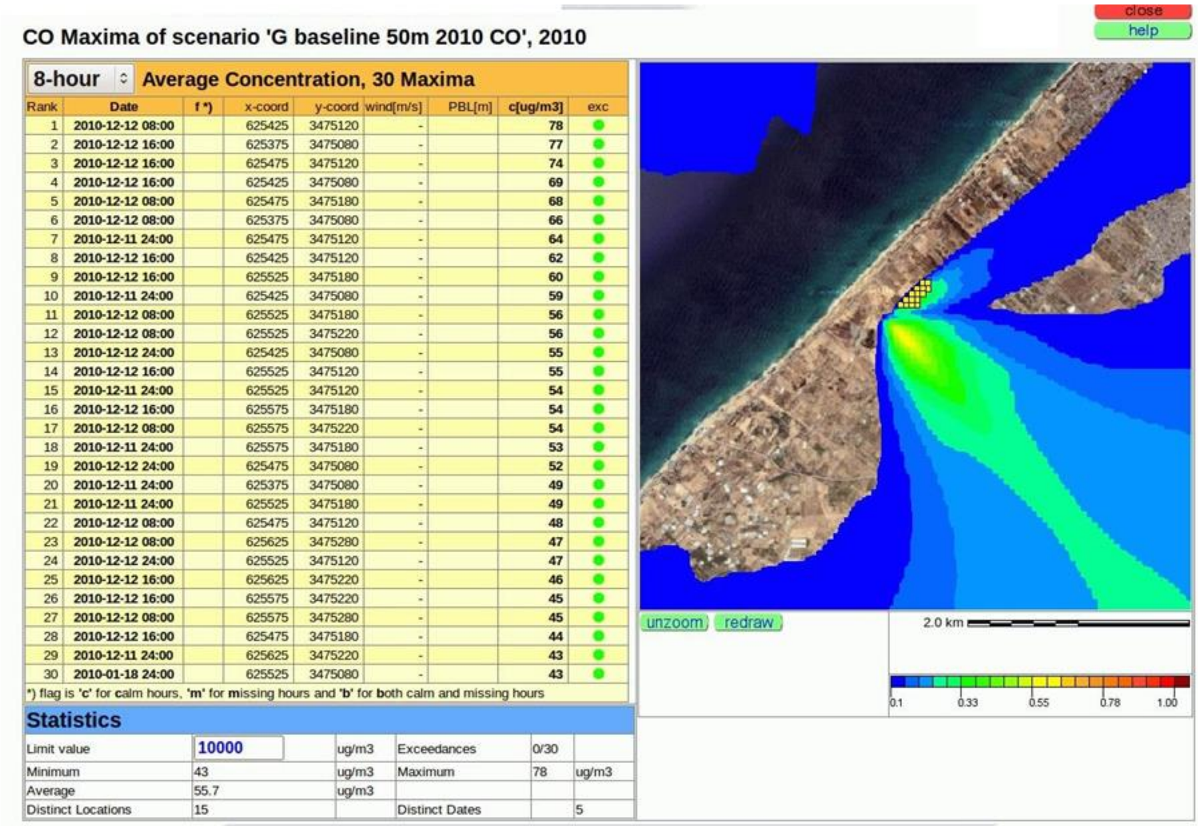
Consistent with this simple arithmetic argument, 8 hour maxima are 70 (2014) and 78 (2010) - and thus well below 10,000 as predicted by plain logic.

As “predicted” by simple arithmetic argument, 8 hour average values are be-low the hourly maxima and thus necessarily well below the limit value of 10,000. Q.E.D.

Concentrations in µg/m3

Year	Hourly maxima µg/m^3	8 hour max. µg/m^3	N. exceedances	compliance
2010	110.8	78	0	
2014	94.0	70	0	

Table 19: CO Concentrations (µg/m3)



CO Maxima of scenario 'G baseline 50m 2010 CO', 2010

8-hour Average Concentration, 30 Maxima

Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-12 08:00		625425	3475120	-		78	
2	2010-12-12 16:00		625375	3475080	-		77	
3	2010-12-12 16:00		625475	3475120	-		74	
4	2010-12-12 16:00		625425	3475080	-		69	
5	2010-12-12 08:00		625475	3475180	-		68	
6	2010-12-12 08:00		625375	3475080	-		66	
7	2010-12-11 24:00		625475	3475120	-		64	
8	2010-12-12 16:00		625425	3475120	-		62	
9	2010-12-12 16:00		625525	3475180	-		60	
10	2010-12-11 24:00		625425	3475080	-		59	
11	2010-12-12 08:00		625525	3475180	-		56	
12	2010-12-12 08:00		625525	3475220	-		56	
13	2010-12-12 24:00		625425	3475080	-		55	
14	2010-12-12 16:00		625525	3475120	-		55	
15	2010-12-11 24:00		625525	3475120	-		54	
16	2010-12-12 16:00		625575	3475180	-		54	
17	2010-12-12 08:00		625575	3475220	-		54	
18	2010-12-11 24:00		625575	3475180	-		53	
19	2010-12-12 24:00		625475	3475080	-		52	
20	2010-12-11 24:00		625375	3475080	-		49	
21	2010-12-11 24:00		625525	3475180	-		49	
22	2010-12-12 08:00		625475	3475120	-		48	
23	2010-12-12 08:00		625625	3475280	-		47	
24	2010-12-12 24:00		625525	3475120	-		47	
25	2010-12-12 16:00		625625	3475220	-		46	
26	2010-12-12 16:00		625575	3475220	-		45	
27	2010-12-12 08:00		625575	3475280	-		45	
28	2010-12-12 16:00		625475	3475180	-		44	
29	2010-12-11 24:00		625625	3475220	-		43	
30	2010-01-18 24:00		625525	3475080	-		43	

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	10000	ug/m3	Exceedances	0/30	
Minimum	43	ug/m3	Maximum	78	ug/m3
Average	55.7	ug/m3			
Distinct Locations	15		Distinct Dates		5

Figure 38: CO, 8 hour maxima

11. SENSITIVITY ANALYSIS

Sensitivity analysis explores the model response to a systematic variation of selected parameters such as emissions and emission relevant parameters (e.g., fuel/quality, operating conditions), meteorology, stack parameters with tabular summaries and direct comparison of results matrices (receptor grids).

Candidates for sensitivity analysis include:

- Basic emission estimates: Operations/configuration: 2 or 3 engines, diesel or natural gas
- Stack height
- Year of meteorology

Emission scenarios:

Source configuration	NOx	SO2	PM10	CO
3 engines on diesel	33.40	11.0	0.50	8.90
2 engines on diesel + PV addition	22.27	7.0	0.33	5.93
3 engines on natural gas	2.00	0	0	0.90

Table 20: Emission scenarios (µg/m^{3})

Results for the three cases tested clearly shows that while the model is linear in emissions for average and maxima, it is non-linear for the threshold function that defines exceedances; the "worst case" meteorology (in terms of numbers of hourly exceedances) is used for the comparison of different emission scenarios; results for NO2/NOx:

Emissions scenario	Annual average (µg/m^{3})	Annual maximum (µg/m^{3})	hourly maximum (µg/m^{3})	Number of violations
3 * diesel	**0.445**	**2.26**	**582**	**>30**
2 diesel	**0.296**	**1.50**	**387**	**0**
3* nat. gas	**0.027**	**0.135**	**35**	**0**

Table 21: Emission scenarios for NO2/NOx (µg/m^{3})

Please note that the number of annual exceedances at the sensitive receptor location "Chalet" even for the worst case emission scenario is 6 (in only one year) and thus well below the allowable number of violations of 18 per year (2008/50/EC) concentration predicted for the receptor location are in compliance. Please note that what complies with national hourly standard (400µg), exceeds the EU standard (200 µg), but that provides for up to 18 exceedances per year.

Stack height

Using the baseline emissions (3 diesel engines) and the 2010 "worst case" meteorology, different stack heights are compared in terms of resulting annual domain average, annual maximum, hourly maximum, number of hourly violations (against national standards). Stack height is probably the most cost effective mitigation measure in term of near-field ambient NO2 concentrations.

Stack height	**Annual average (µg/m^{3})**	**Annual maximum (µg/m^{3})**	**hourly maximum (µg/m^{3})**	**Number of violations**
6.5 m	0.445	2.26	**582**	**>30**
10 m	0.426	1.77	354	0
15 m	0.393	1.37	241	0
20 m	0.359	1.12	171	0
25 m	0.327	0.95	126	0

Table 22: Stack height for NO2/NOx (µg/m^{3})

Note: while a 10m stack seems sufficient to meet the national limit value of 400 µg/m^{3}; to meet the EU standard of 200 µg/m^{3}, a 20 m stack would be needed. ORANGE indicates a violation of the IPPC 3% annual mean incremental concentration.

Model grid resolution

AERMOD as a Gaussian model yields an analytical solution for individual receptor points. The concept of "resolution" in sense of finite element or difference or CFD (computational fluid dynamics) Eulerian model does not apply. Resolution must be interpreted as the spacing or density of receptor grid.

Grid resolution	annual average (μg/m³)	annual max (μg/m³)	hourly max (μg/m³)	N.of violations
20 m	0.445	2.26	596	>30
50m	0.445	2.26	582	>30
100m	0.446	2.21	499	9
250m	0.445	1.70	483	1
500m	0.433	1.43	296	2

Table 23: Model grid resolution

NOTE: for the comparison of scenarios, the 50 m grid spacing has been used.

Domain size

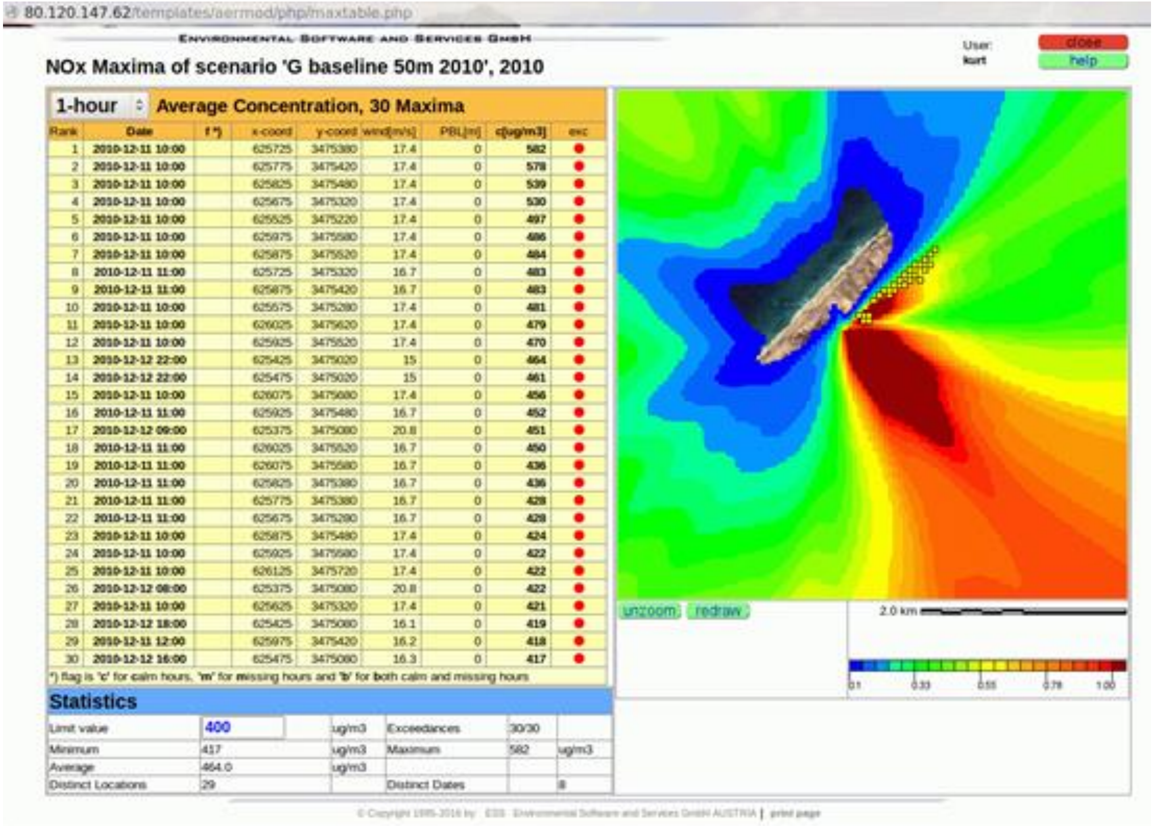
AERMOD as a Gaussian steady state model has no concept of initial or boundary conditions, and the analytical "precise"" solution at any grid point is completely independent on all other aspects of the model configuration. However, to help understand the dependency of the annual average values of the (arbitrary) model domain, a comparison of this indicator (meaningful only for scenario comparison) is given below.

Domain size	annual average (μg/m³)	annual max (μg/m³)	hourly max (μg/m³)	N.of violations
10 km	0.471	2.26	582	>30
5 km	0.445	2.26	582	>30
4 km	0.439	2.26	582	>30
3 km	0.458	2.26	582	>30
2 km	0.554	2.26	582	>30

Table 24: Domain size

NOTE: all domains are symmetric around the common centre (source location) for the comparison of scenarios, the 50 m grid spacing has been used.

The domain size independent number of exceedances clearly shows, that all exceedances are found in the immediate neighbourhood of the source. (see the screen dumps for different domains below).


80.120.147.62/templates/aermod/php/maxtable.php

ENVIRONMENTAL SOFTWARE AND SERVICES GMBH

User: kurt

close
help

NOx Maxima of scenario 'G baseline 50m 2010', 2010

1-hour Average Concentration, 30 Maxima

Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-11 10:00		625725	3475380	17.4	0	582	●
2	2010-12-11 10:00		625775	3475420	17.4	0	578	●
3	2010-12-11 10:00		625825	3475480	17.4	0	539	●
4	2010-12-11 10:00		625675	3475320	17.4	0	530	●
5	2010-12-11 10:00		625525	3475220	17.4	0	497	●
6	2010-12-11 10:00		625975	3475580	17.4	0	486	●
7	2010-12-11 10:00		625875	3475520	17.4	0	484	●
8	2010-12-11 11:00		625725	3475320	16.7	0	483	●
9	2010-12-11 11:00		625875	3475420	16.7	0	483	●
10	2010-12-11 10:00		625575	3475280	17.4	0	481	●
11	2010-12-11 10:00		626025	3475620	17.4	0	479	●
12	2010-12-11 10:00		625925	3475520	17.4	0	470	●
13	2010-12-12 22:00		625425	3475020	15	0	464	●
14	2010-12-12 22:00		625475	3475020	15	0	461	●
15	2010-12-11 10:00		626075	3475680	17.4	0	456	●
16	2010-12-11 11:00		625925	3475480	16.7	0	452	●
17	2010-12-12 09:00		625375	3475080	20.8	0	451	●
18	2010-12-11 11:00		626025	3475520	16.7	0	450	●
19	2010-12-11 11:00		626075	3475580	16.7	0	436	●
20	2010-12-11 11:00		625825	3475380	16.7	0	436	●
21	2010-12-11 11:00		625775	3475380	16.7	0	428	●
22	2010-12-11 11:00		625675	3475280	16.7	0	428	●
23	2010-12-11 10:00		625875	3475480	17.4	0	424	●
24	2010-12-11 10:00		625925	3475580	17.4	0	422	●
25	2010-12-11 10:00		626125	3475720	17.4	0	422	●
26	2010-12-12 08:00		625375	3475080	20.8	0	422	●
27	2010-12-11 10:00		625625	3475320	17.4	0	421	●
28	2010-12-12 18:00		625425	3475080	16.1	0	419	●
29	2010-12-11 12:00		625975	3475420	16.2	0	418	●
30	2010-12-12 16:00		625475	3475080	16.3	0	417	●

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	400	ug/m3	Exceedances	30/30	
Minimum	417	ug/m3	Maximum	582	ug/m3
Average	464.0	ug/m3			
Distinct Locations	29		Distinct Dates	8	

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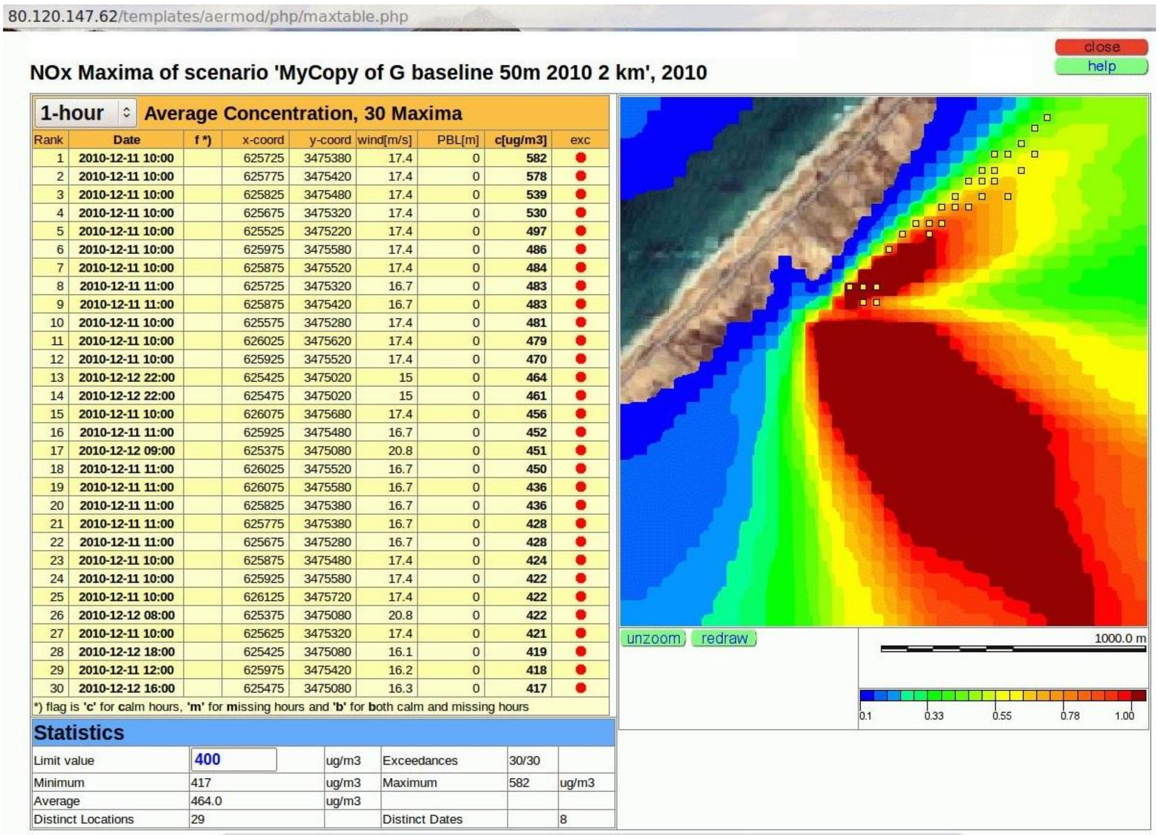
Figure 39: Locations of hourly maxima (NOx), 5 km domain: yellow symbols towards the NE


80.120.147.62/templates/aermod/php/maxtable.php

close
help

NOx Maxima of scenario 'MyCopy of G baseline 50m 2010 2 km', 2010

1-hour Average Concentration, 30 Maxima

Rank	Date	f *)	x-coord	y-coord	wind[m/s]	PBL[m]	c[ug/m3]	exc
1	2010-12-11 10:00		625725	3475380	17.4	0	582	●
2	2010-12-11 10:00		625775	3475420	17.4	0	578	●
3	2010-12-11 10:00		625825	3475480	17.4	0	539	●
4	2010-12-11 10:00		625675	3475320	17.4	0	530	●
5	2010-12-11 10:00		625525	3475220	17.4	0	497	●
6	2010-12-11 10:00		625975	3475580	17.4	0	486	●
7	2010-12-11 10:00		625875	3475520	17.4	0	484	●
8	2010-12-11 11:00		625725	3475320	16.7	0	483	●
9	2010-12-11 11:00		625875	3475420	16.7	0	483	●
10	2010-12-11 10:00		625575	3475280	17.4	0	481	●
11	2010-12-11 10:00		626025	3475620	17.4	0	479	●
12	2010-12-11 10:00		625925	3475520	17.4	0	470	●
13	2010-12-12 22:00		625425	3475020	15	0	464	●
14	2010-12-12 22:00		625475	3475020	15	0	461	●
15	2010-12-11 10:00		626075	3475680	17.4	0	456	●
16	2010-12-11 11:00		625925	3475480	16.7	0	452	●
17	2010-12-12 09:00		625375	3475080	20.8	0	451	●
18	2010-12-11 11:00		626025	3475520	16.7	0	450	●
19	2010-12-11 11:00		626075	3475580	16.7	0	436	●
20	2010-12-11 11:00		625825	3475380	16.7	0	436	●
21	2010-12-11 11:00		625775	3475380	16.7	0	428	●
22	2010-12-11 11:00		625675	3475280	16.7	0	428	●
23	2010-12-11 10:00		625875	3475480	17.4	0	424	●
24	2010-12-11 10:00		625925	3475580	17.4	0	422	●
25	2010-12-11 10:00		626125	3475720	17.4	0	422	●
26	2010-12-12 08:00		625375	3475080	20.8	0	422	●
27	2010-12-11 10:00		625625	3475320	17.4	0	421	●
28	2010-12-12 18:00		625425	3475080	16.1	0	419	●
29	2010-12-11 12:00		625975	3475420	16.2	0	418	●
30	2010-12-12 16:00		625475	3475080	16.3	0	417	●

*) flag is 'c' for calm hours, 'm' for missing hours and 'b' for both calm and missing hours

Statistics

Limit value	400	ug/m3	Exceedances	30/30	
Minimum	417	ug/m3	Maximum	582	ug/m3
Average	464.0	ug/m3			
Distinct Locations	29		Distinct Dates	8	

Figure 40: Locations of hourly maxima (NOx) , 2 km domain: yellow symbols towards the NE

12. MITIGATION MEASURES

The obvious mitigation measure are emission reductions, i.e., the conversion to natural gas and/or the addition of a Photovoltaic system or wind power to reduce the combustion engine use by 1/3.

Please note that these considerations are exclusively based on local emissions, and do not consider the total cost (life cycle analysis) of alternative fuels or configuration.

Another (local) mitigation strategy would be the increase of stack height, an extension from 6.5 to 10m would meet national, an extension to 20m EU standards for the hourly NO_2/NO_X values (based on the worst case assumptions of the 2010 meteorology).

Finally, in principle the conversion to a more efficient desalination technology may also reduce power requirements and thus emissions. No information on the desalination process and it efficiency itself is available, however.

Note that any one of the measure simulated above would lead to complete compliance by national standards, and any number of combinations could also meet any one of the more stringent international standards.

13. GREENHOUSE GAS EMISSIONS (GHG)

13.1 Introduction

One of the most important problems nowadays, which is becoming increasingly acute, is the scarcity of fresh water of adequate quality for human consumption and for industrial and agricultural use. Increasing world population, together with increasing industrial and agricultural activities, has led to excessive exploitation of available water resources and pollution of freshwater resources. Hence, the supply of fresh water is becoming scarcer. Alternative water technology options need to be considered for the long-term guaranteed supply of water for agricultural, commercial, domestic and industrial purposes. Seawater is an alternative source of water for human consumption, because seawater can be desalinated and supplied in large quantities to a very high quality.

While seawater desalination is a promising option, the technology **requires a large amount of energy which is typically generated from fossil fuels**. The combustion of fossil fuels emits greenhouse gases (GHG) and, is implicated in climate change. In addition to environmental emissions from electricity generation for desalination, greenhouse gases are emitted in the production of chemicals and membranes for water treatment (Biswas 2009).

The National Climate Change Adaptation Strategy and the accompanying Plan launched in 2010 by the Palestinian Government, identify water insecurity as one of the main priority for action. Climate change is also given consideration within the National Development Plan 2014-2016 which identifies the promotion of effective adaptation strategies among its most important policies. At the institutional level, responsibilities on climate change issues and on environmental protection/conservation are assigned to the Environment Quality Authority (EQA) within the Palestinian Government, in cooperation with the Ministry of Agriculture and the Palestinian Water Authority according to agreed planning priorities.

On 17th March 2016 the State of Palestine upgraded its status from “Observer” to “Party” to the UNFCCC, becoming its 197th member. This follows the deposit of Palestine’s instrument of accession on December 18th 2015, announced with pride during the closing statements at COP21. This formal entry comes after the United Nation recognition of Palestinian statehood in 2012 and the subsequent invitation by the UNFCCC to join the Convention in July 2014. The first time Palestine participated in climate talks was in 2009 at COP15 in Copenhagen and in the form of “observer entity” (International Climate Policy, 2016)

Palestine has now become a Party to the UNFCCC; therefore it is important to making its contribution to the solution of this global challenge and to quantify greenhouse gas emissions from all sectors in the country, including the planned desalinated water production (GCDP).

Energy systems are for most economies largely driven by the combustion of fossil fuels. During combustion the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide (CO2) and water (H2O), releasing the chemical energy in the fuel as heat. This heat is generally then either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity or for transportation. The energy sector is usually the most important sector in greenhouse gas emission inventories, and typically contributes over 90 percent of the CO2 emissions and 75 percent of the total greenhouse gas emissions in developed countries. CO2 accounts typically for 95 percent of energy sector emissions with methane and nitrous oxide responsible for the balance. Stationary combustion is usually responsible for about 70 percent of the greenhouse gas emissions from the energy sector. About half of these emissions are associated with combustion in energy industries mainly power plants and refineries. Mobile combustion (road and other traffic) causes about one quarter of the emissions in the energy sector (IPCC 2006).

13.2 Emissions of CO2 equivalent

Determining the full implications of the greenhouse gas emissions of an energy system, using the IPCC Bottom-up methodology, requires examination of every phase of the entire energy chain, from the supply side of the system (i.e., resources, electric power plants) to the demand side (i.e., industrial plants, residential and commercial units).

- The used methodology (IPCC 2006 Guidelines) in the calculation of GHG emissions converted as CO2 equivalent were undertaken to describe the aggregated total CO2 emission caused by burning of fossil fuels from the GCDP Phase (I) in the fossil power plant (reciprocating engines) can either be fired by diesel or by natural gas, whatever is available. (IPCC 2006).

Some technical details of the power plant Option that will be used in GCDP plant (engines, boiler plant, thermal rating and the location) and fuel type to be used were provided as below:

Usually, in most of the other countries the desalination plants and other industrial facilities or installations will be connected to the general grid of the country, however, and because the general grid in Gaza strip could not fulfil with the needs of the GCDP (24-25 MW) many Option and proposals were investigated in the preliminary design to avail the necessary power supply, they were as follow:

- Connecting with other grids like the Israeli 166 KV grid, "*Almatahen*" 22 KV grid, Egyptian grid, new Israeli power plant in the north, but all of those options are not part of this study accordingly, the study concluded the following power supply sources.
- Fossil power plant of 4x7.6 MW diesel/gas reciprocating engines (28-30 MW), but due to the expensive cost of the diesel fuel oil imported from Israel and in the absence of the gas source, other renewable energy sources were studied like.
- Off-site photovoltaic plant in area of 100.000 m^2 (12 MW).
- On-site photovoltaic plant on the roof of the R.O. building (2.5 MW).
- 2x2 MW wind turbines to be installed along the shore in front of the GCDP site (4 MW), those wind miles will be of 95 m height and the radius of the blade will be of 50 m long.

To save from the fuel cost in the running operation of the plant will be used **2 or 3 reciprocating engines** in addition to the renewable energy sources according to the weather conditions (sunny or cloudy).

13.3 Calculation of CO2 emissions

In general, emissions of each greenhouse gas from stationary sources are calculated by multiplying fuel consumption by the corresponding emission factor.

EQUATION 1: Greenhouse gas emissions from stationary combustion

$\textit{Emissions}_{GHG,\,fuel} = \textit{Fuel Consumption}_{fuel} \times \textit{Emission Factor}_{GHG,\,fuel}$	**(1)**

Where:

Emissions $_{GHG,fuel}$: emissions of a given GHG by type of fuel (kg GHG)

Fuel Consumption$_{fuel}$: amount of fuel combusted (TJ)

Emission Factor$_{GHG,fuel}$: default emission factor of a given GHG by type of fuel (kg gas/TJ). For CO_2, it includes the carbon oxidation factor, assumed to be 1.

To calculate the total emissions by gas from the source category, the emissions as calculated in Equation (1) are summed over all fuels:

EQUATION 2: Total emissions by greenhouse gas

$\textit{Emissions}_{GHG} = \sum_{fuels} \textit{Emission}_{GHG,\,fuel}$	**(2)**

Applying a Tier 2 approach requires:

- Data on the amount of fuel combusted in the source category;
- A country-specific emission factor for the source category and fuel for each gas.

Under Tier 2, the Tier 1 default emission factors in Equation (1) are replaced by country-specific emission factors. Country-specific emission factors can be developed by taking into account country-specific data, for example carbon contents of the fuels used, carbon oxidation factors, fuel quality and (for non-CO2 gases in particular) the state of technological development. The emission factors may vary over time and, for solid fuels, should take into account the amount of carbon retained in the ash, which may also vary with time.

A country-specific emission factor can be identical to the default one or it may differ. Since the country-specific value should be more applicable to a given country's situation, it is expected that the uncertainty range associated with a country-specific value will be smaller than the uncertainty range of the default emission factor. This expectation should mean that a Tier 2 estimate provides an emission estimate with lower uncertainty than a Tier 1 estimate.

Emissions can be also estimated as the product of fuel consumption on a mass or volume basis, and an emission factor expressed on a compatible basis.

13.4 CO2 emission estimates

The amount of CO2 produced when a fuel is burned is a function of the carbon content of the fuel. The heat content, or the amount of energy produced when a fuel is burned, is mainly determined by the carbon (C) and hydrogen (H) content of the fuel. Heat is produced when C and H combine with oxygen (O) during combustion. Natural gas is primarily methane (CH4), which has higher energy content relative to other fuels, and thus, it has a relatively lower CO2-to-energy content. Water and various elements, such as sulfur and non-combustible elements in some fuels reduce their heating values and increase their CO2-to-heat contents.

- Applying (Equation 1) based on 20 m3/day of fuel consumption (diesel) to operate Fossil power plant of (3x7.6 MW) diesel/gas reciprocating engines (28-30 MW) and standard emission coefficient (2.69 kg CO2 per liter) of diesel, total annual CO2 emissions are estimates at 15000 * 365 * 2.7 = **14.783 tons per year**.

- **Estimated scenarios of annual CO_2 emissions from GCDP:**

GCDP, power supply options	**fuel consumption**		**Electricity** (MWh)	**CO_2** (tons/a)
	Diesel (Liter/a)	**NG** (m^3/a)		
Electricity grid			25	**17.239**
4 engines on diesel	7300	0		**19.710**
3 engines on diesel	**5475**	**0**		**14.783**
2 engines on diesel + PV addition	3650	0		**9.855**
1 engines on diesel + PV + WE	1825	0		**4.928**
4 engines on natural gas	0	7300		**14.600**
3 engines on natural gas	0	5475		**10.950**
• *PV: Photovoltaic, WE: Wind Energy*				

Table 25: Estimated scenarios of annual CO2 emissions from GCDP

13.5 A life cycle assessment (LCA)

The energy intensity of water in most nations is both significant and increasing as water is sourced from deeper or further away. Seawater desalination, in most cases the most energy intensive of potential water sources, will add in a significant way to an existing process. (Cooley et. al.,2006)

Spain's Carboneras desalination plant uses one third of the electricity supplied to Almeria province (Downward, et. al.,2007). CO2 emissions vary depending on fuel mix, most facilities were coupled with power generation plants. Likewise Reverse Osmosis (RO) emissions varied considerably with the fuel mix used for power generating, from **0.08 kg** of CO2/m3 in Norway to **3.08 kg** of CO2/m3 in Portugal (Phil Dickie, 2007).

In general, the increased demand for energy for desalination implies a commensurate increase in the carbon emissions linked to climate change. Worldwide, the electrical power generating sector is the world's most significant single generator of carbon emissions, responsible for 37 per cent of global emissions.

Always operating large scale desalination plants are also generally unsuited for variable power sources and tend to add to the base load power requirements most likely to be generated by burning fossil fuels. A comparison of the emissions intensity of various desalination technologies – using an average European fuel mix for power generation – showed the great advantage of RO (1.78kg CO2 per m3 of produced water) over the thermal distillation technologies of multistage flash (MSF) (**23.41 kg CO2/m3**) or multiple effect distillation (MED) (18.05 kg CO2/m3). (Raluy, Gemma et. al. 2005).

The system boundary of the LCA mainly consists of three stages: seawater extraction, treatment and delivery. The analysis found that the equivalent of 3,890 tonnes of CO_2 could be emitted from the production of 1 GL of desalinated water (Biswas W. K., 2009).

A rough estimation of the life cycle assessment (LCA) can be estimating the greenhouse gas emissions from the production of 1 Giga Litre (GL) of water from the GCDP.

If we take in the consideration the worst case of CO_2 emissions (14,783 tons per year) to produce 55 million m3/a (55 GL/a) Desalinated Water, then this lead to rough estimation of the Life cycle assessment (LCA) for the GCDP as follow:

LCA is (14,783 tons/a) CO_2 / (55 GL/a) = 268.7 Tonnes CO_2 equivalent.

That mean the equivalent of 268.7 tonnes of CO_2 could be emitted from the production of 1 GL of desalinated water.

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