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APICE

WP5.3. Design of scenarios supporting coast development strategies - Barcelona

Design of scenarios supporting coast development strategies - Barcelona

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1. Description of the scenarios selected

APICE in Barcelona has worked out two scenarios:

- Trend scenario 2015. It corresponds to the current trend in the horizon 2015 considering changes already implemented or planned in respect to 2008, as well as the port activity forecast. The emissions have been estimated in previous report *Assessment of air emissions sources in the Port of Barcelona and future scenario*[1].
- Scenario APICE. This scenario considers the implementation of the measures included in the APICE plan in Barcelona, in addition to the trends by 2015. Since the measures are at different time scales, this scenario does not correspond to any specific year.

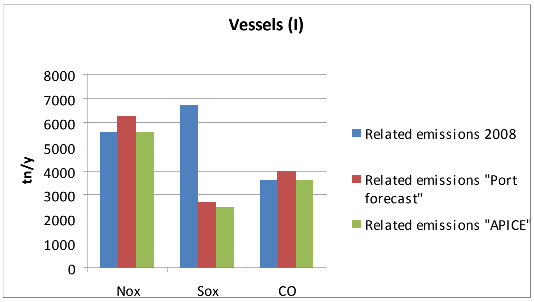
The following table summarizes the characteristics of both scenarios regarding each emission source:

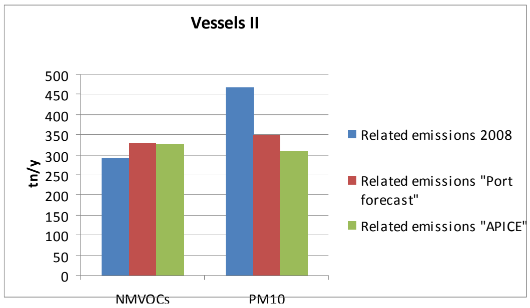
Emission source	Trend scenario 2015	APICE scenario
Vessels	○ Increased number of calls due to increased goods forecast ○ In hotelling phase, reduction of 97,3% SOx and 50% PM10	○ Passengers ferries propelled by LNG (reduction 85% NOx and ~100% Sox and particles) ○ Cold-ironing for 10% of cruise passengers
Tug boats	○ Increased activity according to vessels traffic increased	○ 50% tug boats propelled with LNG
Auxiliary means	○ Increased activity (15%) according to vessels traffic increased	○ No specific mitigation action proposed
Cargo handling	○ Increased activity due to more cargo handling ○ New terminal semi-automated resulting in 45% less emissions	○ TCB terminal machinery converted into natural gas (reduction 50-80% NOx and 90-95% PM). Together with the semi-automated terminal, it is estimated 65% NOx and 80% PM reduction
Solid bulks	○ Increased solid bulks handling according to forecast ○ All measures proposed in 2003 are implemented	○ No specific mitigation action proposed
Heavy-duty vehicles	○ Increased merchandise according to forecast ○ 86,1% of goods transported by truck ○ Distance: 30km within metropolitan area; 4km within port ○ Emissions factors: 10% reduction in respect to 2008)	○ Increased merchandise according to forecast ○ 85% of goods transported by truck ○ Distance: 39,5 km within metropolitan area; 3,5 km within port ○ Emissions factors: 15% reduction in respect to 2008)
Trains	○ Increased merchandise according to forecast ○ 13,9% of goods transported by train ○ Time: 0,25 hours within metropolitan	○ Increased merchandise according to forecast ○ 15% of goods transported by train ○ Time: 0,2 hours within metropolitan

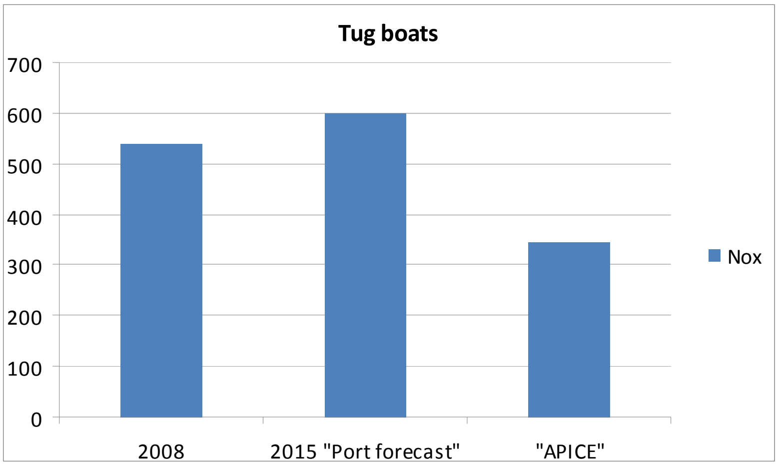
[1] Available at http://www.apice-project.eu/img_web/pagine/files/Results/Risk%20activities/Risk%20activities%20in%20Barcelona.pdf

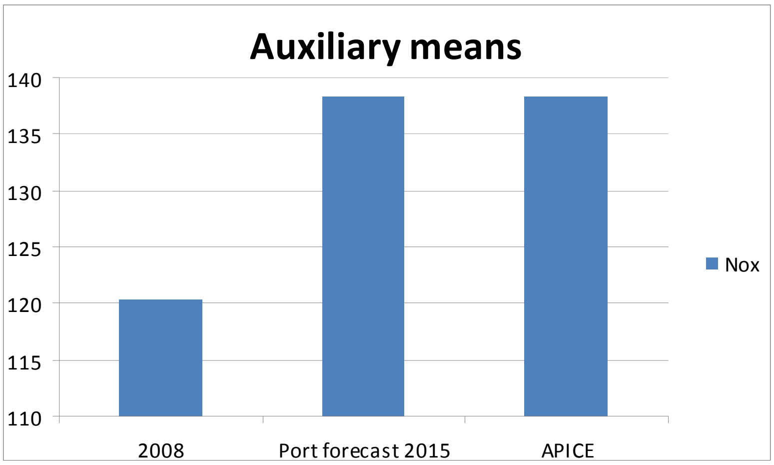
	area; 0,5 hours within port ○ Emissions factors: it's considered EF of locomotives after 1990 according to study[2]	area; 0,5 hours within port ○ Emissions factors: further 10% reduction due to natural gas conversion[3]

Emissions calculation is shown in the annex. The following figures show the emissions in the different scenarios for all emission sources.



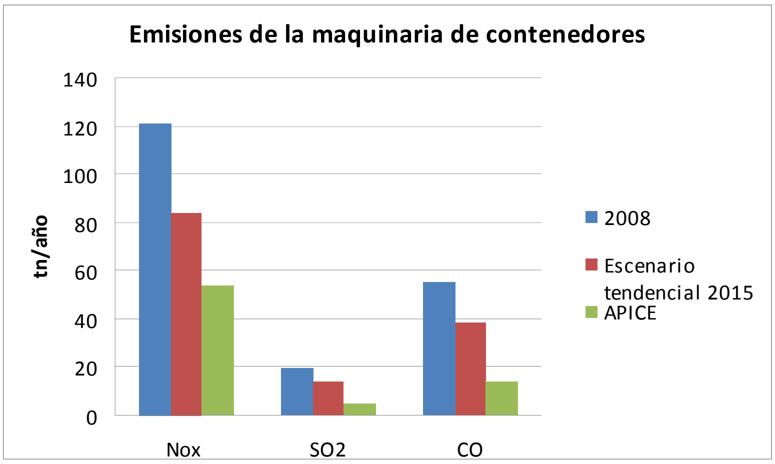


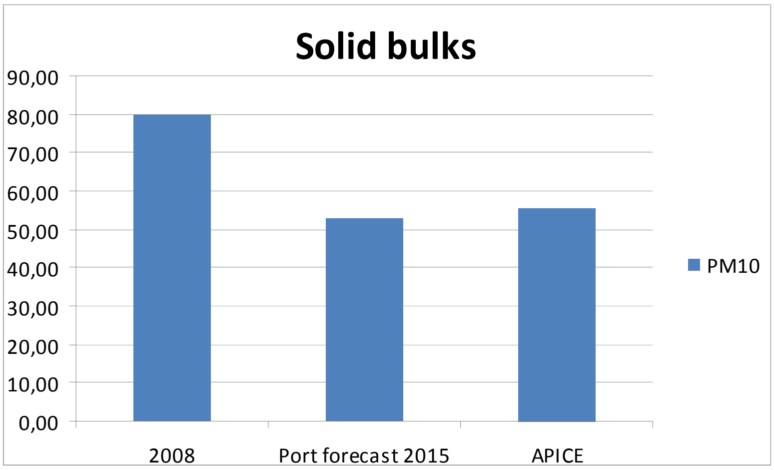


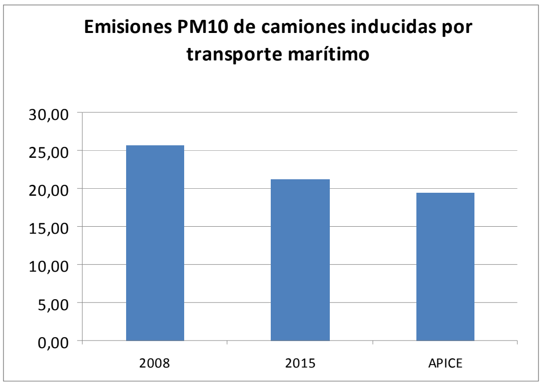


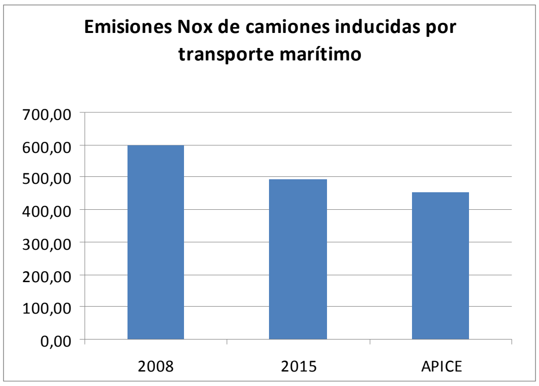
[2] Rail Diesel Study, WP 1 “Status and future development of the diesel fleet”

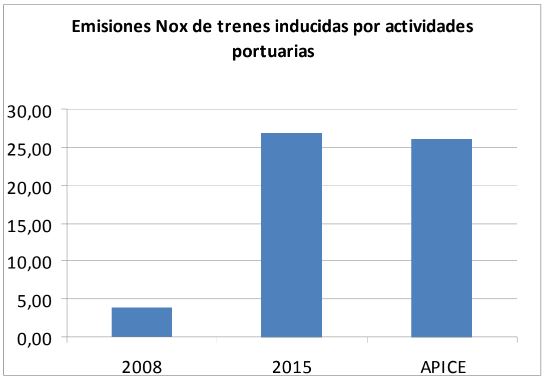
[3] Rail Diesel Study, WP 1 “Status and future development of the diesel fleet”

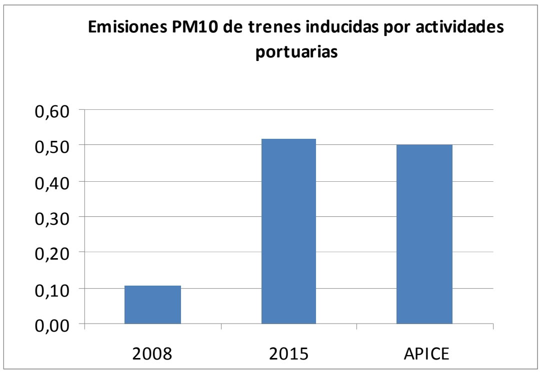




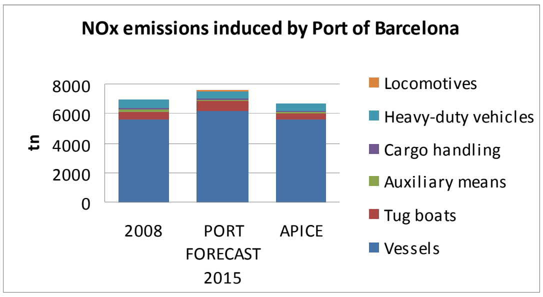


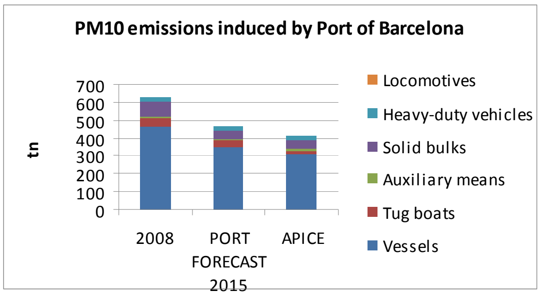


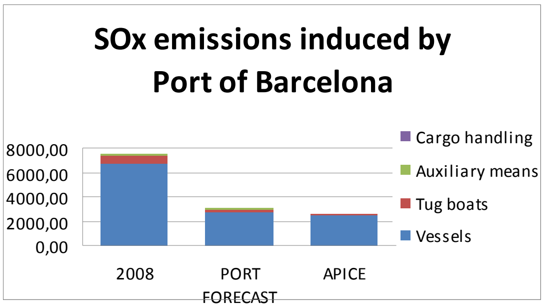


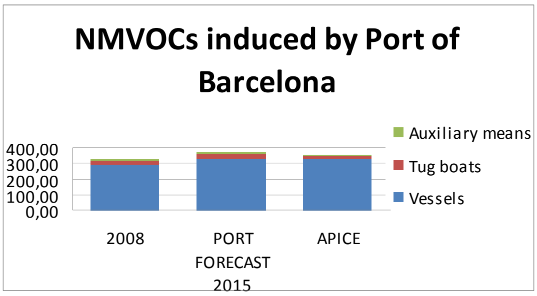


The following figures summarize the overall situation considering all emission sources:









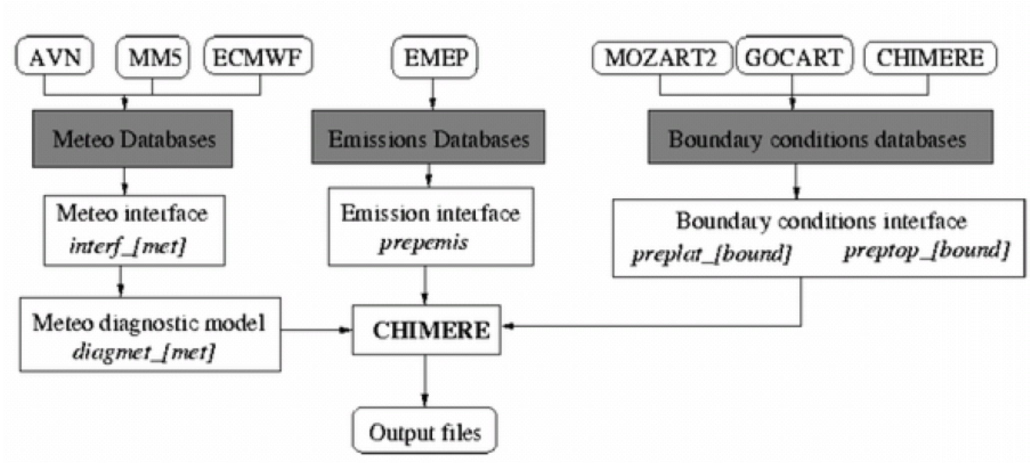
Furthermore, as for the emission sources other than maritime and port, it is considered the scenarios built up by the Generalitat, as it follows:

	NOX					
Àmbit	Escenari 2008		Escenari 2015-Tendencial		Escenari 2015-Pla	
	(t/a)	%	(t/a)	%	(t/a)	%
Industria, combustió i cogeneració de potència <50 MWt	8.537,5	25,0	7.686,3	25,5	6.621,4	24,3
Generació Energia Elèctrica de potència ≥50 MWt	535,2	1,6	545,7	1,8	545,7	2,0
Sector domèstic i de serveis	1.719,2	5,0	1.730,2	5,7	1.713,9	6,3
Trànsit interurbà	8.172,5	23,9	6.538,0	21,7	5.777,9	21,2
Transit urbà	7.980,9	23,4	6.384,7	21,2	5.347,2	19,6
Transport Marítim	5.602,6	16,4	5.609,9	18,6	5.609,9	20,6
Transport Aeri	1.588,0	4,7	1.670,4	5,5	1.638,0	6,0
Total	**34.135,9**	**100,0**	**30.165,2**	**100,0%**	**27.254,0**	**100,0%**

	PM10					
Àmbit	Escenari 2008		Escenari 2015-Tendencial		Escenari 2015-Pla	
	(t/a)	%	(t/a)	%	(t/a)	%
Industria, combustió i cogeneració de potència <50 MWt	447,3	21,5	440,8	23,3	439,0	24,5
Generació Energia Elèctrica de potència ≥50 MWt	8,1	0,4	13,3	0,7	13,3	0,7
Sector domèstic i de serveis	30,4	1,5	30,6	1,6	30,4	1,7
Trànsit interurbà	567,5	27,2	453,6	23,9	400,6	22,4
Trànsit urbà	373,7	17,9	299,0	15,8	250,4	14,0
Transport marítim	469,2	22,5	473,2	25,0	473,2	26,5
Transport aeri	32,2	1,5	33,3	1,8	29,6	1,7
Activitats extractives	156,4	7,5	151,5	8,0	151,5	8,5
Total	**2.084,8**	**100,0**	**1.895,3**	**100,0**	**1.788,0**	**100,0**

2. Description of the set-up of the modeling system

The APICE modelling system relies on the combination of MM5-CHIMERE modules, plus the addition of the modified EMEP emissions. The meteorological model is the Fifth-Generation Pennsylvania State University - National Center for Atmospheric Research Mesoscale Model (MM5) [Dudhia, 1993; Grell et al., 1994]. Different versions of the model have been extensively used in a number of regional simulations (e.g. Boo et al. [2006]; Tagaris et al. [2007]; Nunez et al. [2009]; Lynn et al. [2010]; Gómez-Navarro et al. [2010], among many others). The Chemistry Transport Model (CTM) selected is the CHIMERE chemistry transport model [Schmidt et al., 2001; Bessagnet et al., 2004; Rouil et al., 2009]. MELCHIOR2 gas-phase mechanism is implemented within CHIMERE [Derognat et al., 2003]. The structure of the model and the processes solved can be found in the figure below. The physico-chemical options for the regional modelling system (table below) have been chosen in order to minimize the computational cost, since none of the configurations included provides the best performance for all seasons and locations [Fernández et al., 2007].



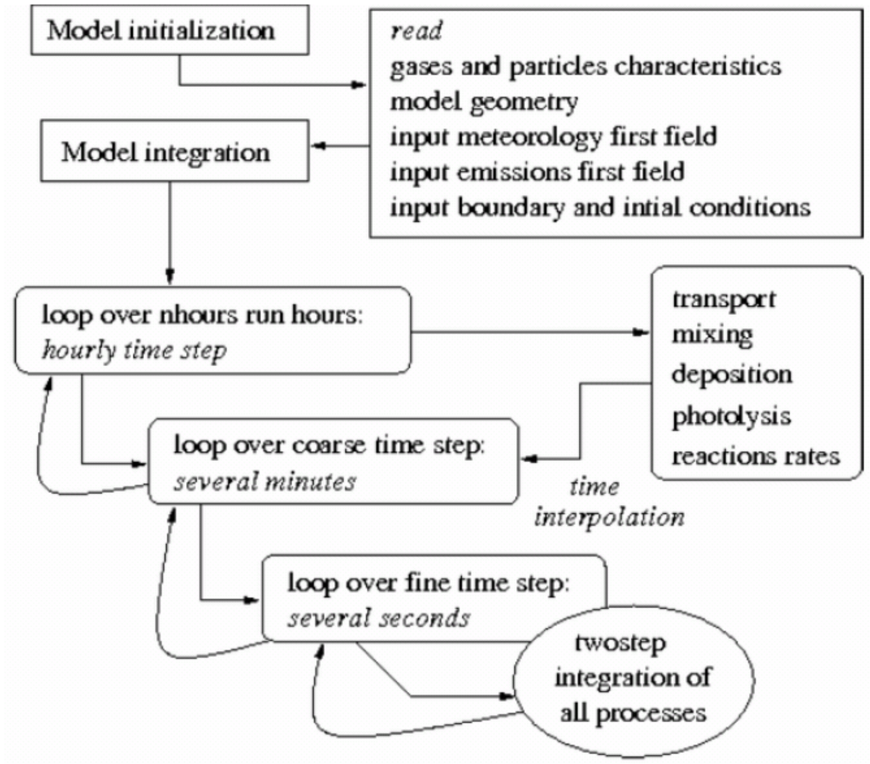


Figure. Structure and processes solved by the CHIMERE chemistry transport model [Bessagnet et al., 2009].

Table. Con_guration and parameterizations of the modeling system used in APICE

MM5	CHIMERE
Microphysics: Simple Ice; Cumulus: Grell; PBL: MRF; Radiation: RRTM; Soil: Noah LSM	Chemical Mechanism: MELCHIOR2; Aerosol chemistry: Inorganic (thermodynamic equilibrium with ISORROPIA module) and organic aerosol chemistry (MEGAN SOA); Natural aerosols: dust, re-suspension and inert sea-salt; BC: LMDz-INCA+GOCART

Summarizing the physico-chemical parameterizations, in APICE we have implemented:

- Gas-phase solver: TWOSTEP based on Gauss-Seidel iteration scheme.
- Horizontal and vertical advection schemes: Van Leer (horizontal) and UPWIND (vertical).
- Vertical diffusion: BLM.
- Deposition: Resistance scheme based on Wesely. Aerosol deposition is also based on Wesely modifed by Seinfeld and Pandis [2006]. Corrections of the vegetal cover have been introduced after.
- Convective mixing (cloud module): Tiedtke parameterization.

The chemistry transport model includes aerosol and heterogeneous chemistry; distinguishes among different chemical aerosol components, namely nitrate, sulphate, ammonium, elemental and organic carbon with three subcomponents (primary, secondary anthropogenic and secondary biogenic) and marine aerosols. Unspecied primary anthropogenic aerosols and aerosol water are additionally kept as separate components. The model considers the thermodynamic equilibrium using the ISORROPIA model [Nenes et al., 1998]. Last, the aerosol microphysical description for CHIMERE is based on a sectional aerosol module including 6 bins from 10 nm to 40 _m using a geometrical progression.

In APICE, boundary conditions for CHIMERE chemistry transport model are based on the global climate chemistry model LMDz-INCA2 (96 _ 72 grid cells, namely 3.75o_ 2.5o in longitude and latitude, with 19 _-p hybrid vertical levels, Szopa et al. [2009]) developed by the Laboratoire des Sciences du Climat et l'Environnement (LSCE). Climatic monthly mean data are interpolated in the horizontal and vertical dimensions to force the major chemical concentrations at the boundaries of the domain. A detailed description of the INteractive Chemistry and Aerosol (INCA) model is presented in Hauglustaine et al. [2004] and Folberth et al. [2006]. In order to avoid the influence of boundary conditions, a blending area of five grid points is excluded from the analysis hereafter.

The spatial model configuration consists of three one-way nested domains of MM5-CHIMERE simulations with spatial resolutions of 10 km (Iberian Peninsula, IP10), 2 km (covering most of Catalonia, BCN02) and 0.5 km (Barcelona Metropolitan Area, BCN005) (figure below). 24 sigma levels are considered in the vertical, with the top at 100 hPa. The fields are interpolated to CHIMERE working grids.

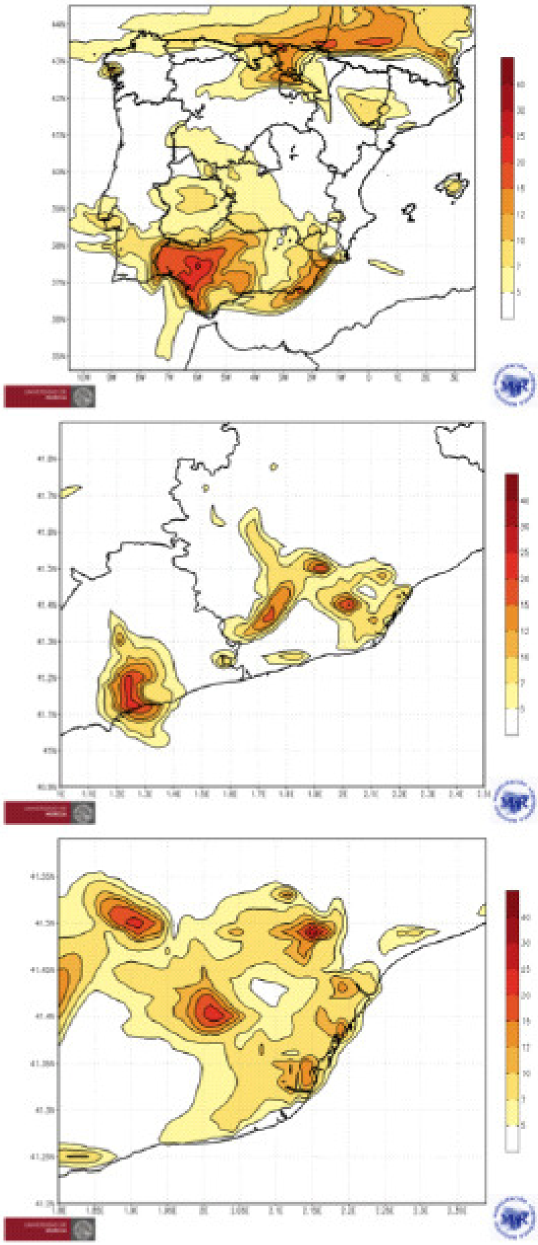


Figure. One-way nested domains with resolution 10km (IP10), 2km (BCN02) and 0.5km (BCN005) used by CHIMERE within APICE.

3 Description of the projected emissions for the Trend Scenario 2015 and APICE Scenario

The emissions are presented in the Annex I. Calculation of emissions in the different scenarios.

4 Results and conclusions

The overall emissions reduction by implementing the APICE measures in Barcelona is 12% both for NOx and PM10 with respect to the trend scenario 2015.

The impact of several future scenarios (year 2015 as the time horizon) including the aforementioned mitigation actions on the air quality of the city of Barcelona were performed using the MM5-CHIMERE modeling system, as described in several works (e.g. Jiménez-Guerrero et al., 2012), including both anthropogenic and natural emissions (biogenic NMVOCs, wind-blown dust and sea salt aerosol). The system has been applied over two nested domains covering (1) the entire Catalonia (120 x 120 km at a resolution of 2 km) and (2) the Barcelona Metropolitan Area (40 x 40 km at a resolution of 0.5 km) (Figure 1). 30 vertical layers up to 100 hPa are used for the simulation of the meteorological conditions, while they are collapsed to 16 layers up to 500 hPa in the CHIMERE configuration. The air quality simulations were performed for a summer and a winter period extending for one month (August 2011 and December 2011) using the corresponding meteorological conditions as simulated by MM5. A spin-up period of 15 days is run prior to the reference periods.

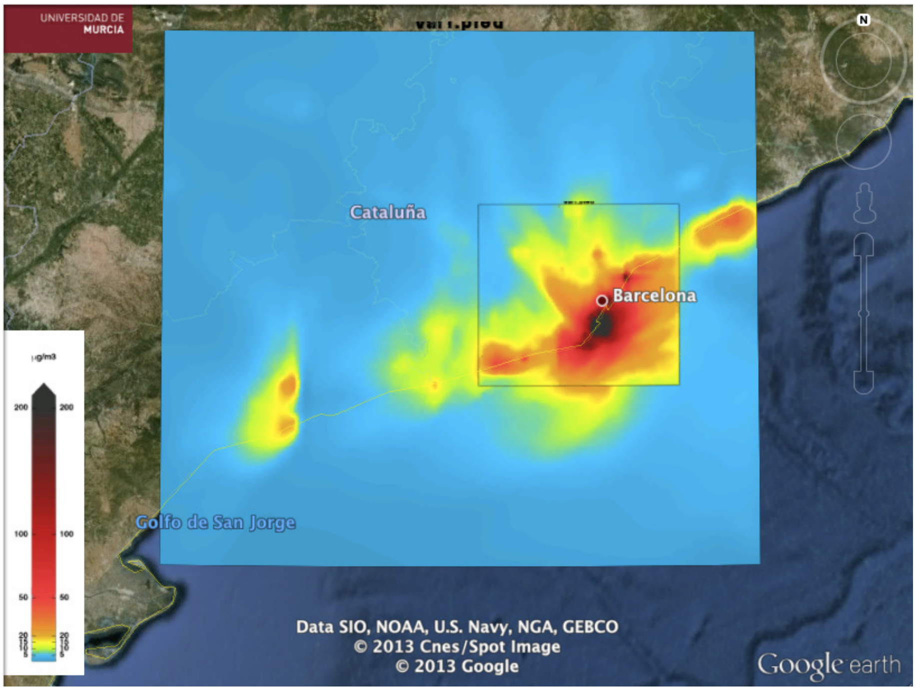


Figure 1: One-way nested domains of study simulated with CHIMERE: Catalonia (BCN02, resolution 2 km) and Barcelona Metropolitan Area (BCN005, resolution 0.5 km). Shaded colours represent the maximum summertime concentrations of sulphur dioxide highlighting the impact of the Barcelona port on the levels of this pollutant.

CHIMERE results are based on the 0.5 km resolution simulations, and cover three different scenarios: (a) the forecast of the emissions for the port in the year 2015, including the trend scenario of emissions predicted by the Catalonia Government for emissions different from the maritime sector (this has been selected as the base-case future scenario, since it represents the forecast of emissions for the year 2015); (b) an analogous scenario to (a), where the emissions for the port include the mitigation measures as defined in APICE; and (c) the plan scenario as defined by the Catalonia Government for the year 2015, where the port emissions include the mitigation actions defined in APICE. Moreover, we include the picture from the 2011 simulations (using 2008 emissions) in order to have an idea of the future evolution of emissions.

For further explanation on the APICE measures, please refer to the document APICE Plan Barcelona.

Figure 2 presents the changes in PM air quality in Barcelona for a summer period (using the meteorology of August 2011) because of the mitigation emission scenarios selected. The maximum decreases in mean PM levels are over the coastal areas, where PM10 values decrease from 80.3 $\mu g\ m^{-3}$ in 2008 to 66.3 $\mu g\ m^{-3}$ in the future base case scenario. Moreover, when comparing the mitigation scenario to 2015 base case scenario, values around -10.2% as maximum reductions are found (very similar reductions, -11.3%, are found in the case of PM2.5 concentrations). For the whole modeling domain, we can observe a reduction in PM10 (PM2.5) levels around -6.1% (-6.3%) in this mitigation scenario. Analogous results are observed in the APICE mitigation + Plan scenario for 2015 (where reductions from other emitting sectors are included), where the maximum reductions downwind the port area are -12.8 and -11.9% for the maximum reductions of PM10 and PM2.5, in that order (-5.7% and -5.4% for the whole modeling domain). That indicates that most of the emission reduction comes from the mitigation measures in the port and not from the rest of planned emissions for other emitting activities.

Analogous results are found for Barcelona in the winter month (simulations using the meteorology of December 2011). The maximum decreases in mean PM levels (Figure 3) are over the coastal areas, and especially over the Barcelona port, where reductions in the order of -10.3% are found as maximum reductions in the scenario including the APICE mitigation measures when compared to the base case scenario for 2015. The results are similar for PM2.5 concentrations, where reductions by -9.9% are modeled as maximum decreases. When considering the mean in the modeling domain, we can observe a reduction in PM10 (PM2.5) levels around -5.6% (-5.2%) in this APICE mitigation + Trend scenario. Similar results are observed in the APICE mitigation + Plan scenario, where the maximum reductions are located near the port: -10.6% and -10.1% for the maximum reductions of PM10 and PM2.5, respectively (-5.2% and -4.9% as mean for the modeling domain). As also found for the summer period, the local mitigation actions significantly impact SO_2 and NO_2 concentrations in the port and surrounding areas.

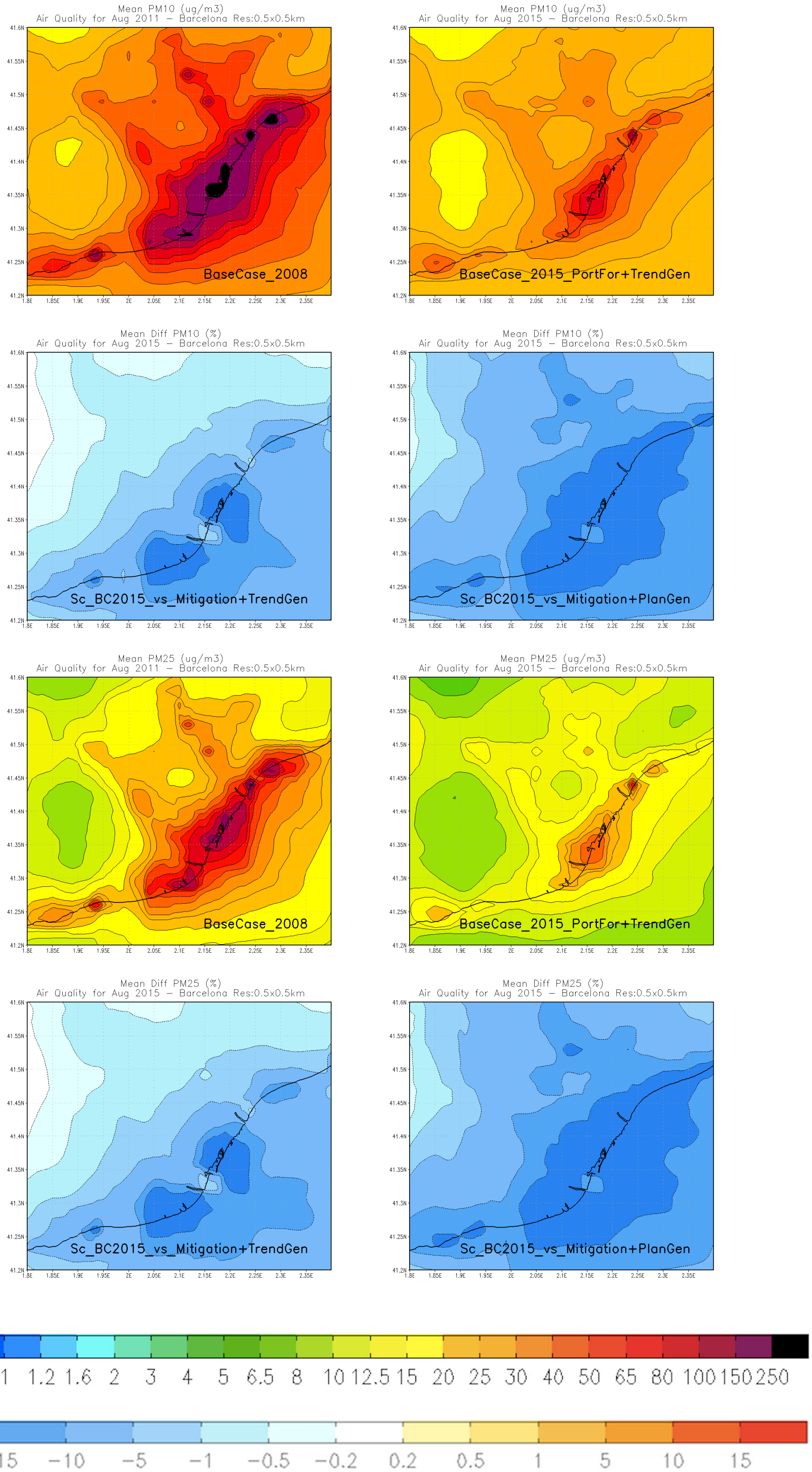


Figure 2: **Top-left: Base-case concentrations of PM10 (top) and PM2.5 (bottom) over the domain for summertime for present-day base case (2008). Top-right: Base-case concentrations of PM10 (top) and PM2.5 (bottom) over the domain for summertime for 2015 base case. The rest of figures indicate the relative difference (%) with the (bottom-left) APICE mitigation measures + Trend scenario; and (bottom-right) APICE mitigation measures + Plan scenario.**

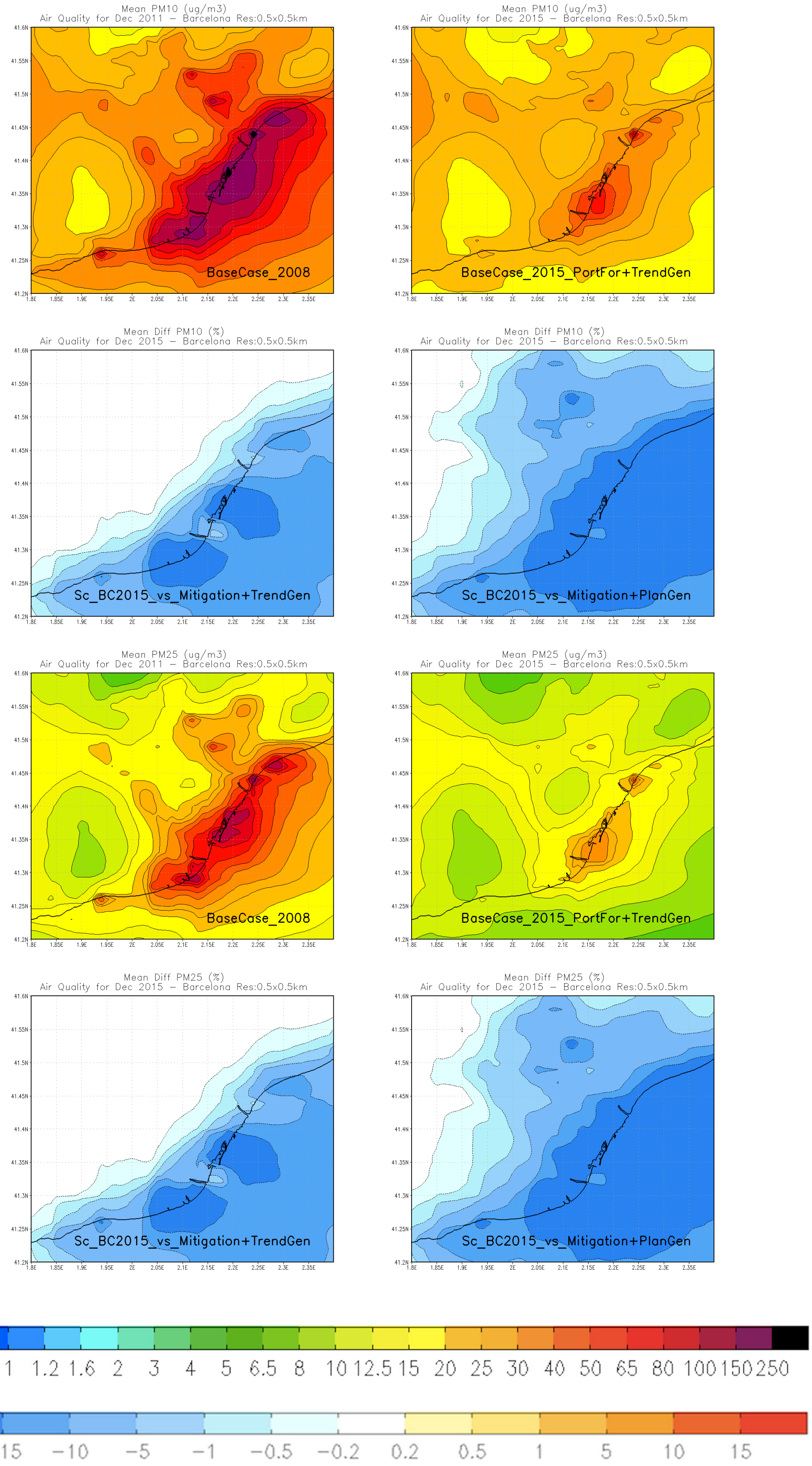


Figure 3: **Top-left: Base-case concentrations of PM10 (top) and PM2.5 (bottom) over the domain for wintertime for present-day base case (2008). Top-right: Base-case concentrations of PM10 (top) and PM2.5 (bottom) over the domain for wintertime for 2015 base case. The rest of figures indicate the relative difference (%) with the (bottom-left) APICE mitigation measures + Trend scenario; and (bottom-right) APICE mitigation measures + Plan scenario.**

Annex I. Calculation of emissions in the different scenarios

Vessels traffic scenarios						
	2008		2015			
	units merchandise	calls	Port forecast		Economic growth/Strategic plan	
cars (units)	438.654	283	676.106	530	950000	744
TEUs	1.797.157	3478	3.253.478	3730	3900000	4297
cruise passengers	2.152.847	820	2.800.000	930	3000000	1000
ferries passengers	1.048.890	2644	1.233.086	2560	1300000	2708
liquid bulk (tn)	12.105.080	1076	14.118.000	1241	17000000	1480
solid bulk (tn)	3.506.472	145	4.018.000	120	4200000	1124
UTIs	341.173	485	370.447	463	400000	500
TOTAL EMISSIONS		8931		9574		11854

Related emissions 2008					Related emissions "Port forecast"					Related emissions "APICE"				
Nox	NMVOCs	PM10	Sox	CO	Nox	NMVOCs	PM10	Sox	CO	Nox	NMVOCs	PM10	Sox	CO
384,07	18,66	29,62			719,05	34,94	55,45			719,05	34,94	55,45		
2214,89	109,76	176,69			2375,37	117,71	189,49			2375,37	117,71	189,49		
684,76	29,54	50,28			776,62	33,50	57,02			725,36	30,15	53,26		
718,30	36,16	60,36			695,48	35,01	58,44			104,32	35,01	0,00		
1039,67	76,90	113,38			1199,10	88,69	130,77			1199,10	88,69	130,77		
358,75	13,84	23,75			296,90	11,45	19,66			296,90	11,45	19,66		
202,12	9,38	15,10			192,98	8,96	14,42			192,98	8,96	14,42		
5602,56	**294,24**	**469,18**	**6768,37**	**3619,12**	**6255,49**	**330,26**	**351,92**	**2753,99**	**4040,90**	**5613,08**	**326,91**	**310,24**	**2471,16**	**3625,91**

Tug boats			
	2008	2015 "Port forecast"	"APICE"
	calls	calls	
cars (units)	283	530	530
TEUs	3478	3730	3730
cruise passengers	820	930	930
liquid bulk (tn)	1076	1241	1241
solid bulk (tn)	145	120	120
UTIs	485	463	463
total calls	6287	7014	7014
Nox	**538,31**	**600,55**	**345,32**

Auxialiary means			
	2008	Port forecast 2015	APICE
increased activity		15%	
Nox	120,33	138,38	138,38

Cargo hadling			
		2015	
	2008	Escenario tendencial 2015	APICE
TEUs	2569549	3253478	3253478
Nox	121,03	84,28	53,63
SO2	19,79	13,78	5,01
CO	55,50	38,65	14,06

solid bulks				
	2003	2008	Port forecast 2015	APICE
total bulk	3468306	3.506.472	4018000	4200000
related PM10	178,85	180,82	207,20	216,58
	no measures	measures 75%	measures 100%	measures 100%
reduction PM10 with measures		100,85	154,08	161,06
PM10	**178,85**	**79,97**	**53,12**	**55,52**

Heavy-duty vehicles							
	2008		2015		APICE		
Tranported tones by road	32687121	tn	29931005	tn	29542655	tn	
Average load	19,8	tn/vehicle	19,8	tn/vehicle	19,8	tn/vehicle	
Average distance within Plan area	30	km	30	km	29,5		
Average distance at port	4	km	4	km	3,5		
Truck movements	1650865	movements	1511667	movements	1492053		
EF Nox	12,1	g/km	10,89	g/km	10,29		
EF PM10	0,52	g/km	0,468	g/km	0,44		
Nox emissions wihin port	**79,90**		**65,85**		**53,71**		tn
PM10 emissions within port	**3,43**		**2,83**		**2,31**		tn
		2008		2015		APICE	
Nox emissions within Plan area	**599,26**		**493,86**		**452,70**		tn
PM10 emissions within Plan area	**25,75**		**21,22**		**19,45**		tn

locomotives emissions							
	2008		2015		APICE		
Number of trains movements	1665	movements	13618		14695		
Average time within port	0,25	h	0,25		0,2		
Average time within Plan area	0,5	h	0,5		0,5		
Average nominal power output	800	kW	800		800		
Average load factor	0,5		0,5		0,5		
Average EF Nox	11,73	g/kW	9,86		8,87		

Average EF PM	0,32	g/kW	0,19		0,17		
Nox emissions within port	**1,95**		**13,43**		**10,43**		tn
PM emissions within port	**0,05**		**0,26**		**0,20**		tn
Nox emission induced in Plan area	**3,91**	**tn**	**26,85**	**tn**	**26,08**	**tn**	
PM emissions induced in Plan area	**0,11**	**tn**	**0,52**	**tn**	**0,50**	**tn**	

Aggregated scenarios: emissions within the port								
2008								
	Vessels	Tug boats	Auxiliary means	Cargo handling	Solid bulks	Heavy-duty vehicles	Locomotives	TOTALS
Nox	5602,56	538,31	120,33	121,03		79,90	1,95	**6464,08**
NMVOCs	294,24	28,27	6,32					**328,83**
PM10	469,18	45,08	10,08		79,97	3,43	0,05	**607,79**
Sox	6768,37	650,33	145,37	19,79				**7583,86**
CO	3619,12	347,74	77,73	55,50				**4100,09**
PORT FORECAST 2015								
	Vessels	Tug boats	Auxiliary means	Cargo handling	Solid bulks	Heavy-duty vehicles	Locomotives	TOTALS
Nox	6255,49	600,55	138,38	84,28		65,85	13,43	**7157,98**
NMVOCs	330,26	31,71	7,31					**369,28**
PM10	351,92	33,79	7,78		53,12	2,83	0,26	**449,69**
Sox	2753,99	264,39	60,92	13,78				**3093,08**
CO	4040,90	387,94	89,39	38,65				**4556,88**
variación Nox	11,65	11,56	15,00	-30,36		-17,59	14,55	
variación NMVOCs	12,24	12,15	15,61					
variación PM10	-24,99	-25,05	-22,75		-33,58	-17,59	20,60	
variación Sox	-59,31	-59,34	-58,09	-30,36				
variación CO	11,65	11,56	15,00	-30,36				
APICE								
	Vessels	Tug boats	Auxiliary means	Cargo handling	Solid bulks	Heavy-duty vehicles	Locomotives	TOTALS
Nox	5664,34	345,32	138,38	53,63		53,71	11,59	**6266,97**
NMVOCs	330,26	20,13	8,07					**358,47**
PM10	308,94	18,83	7,55		53,12	2,31	0,22	**390,97**

Sox	2459,54	149,94	60,09	5,01				**2674,58**
CO	3659,02	223,07	89,39	14,06				**3985,54**
Aggregated scenarios: emissions induced the port								
2008								
	Vessels	Tug boats	Auxiliary means	Cargo handling	Solid bulks	Heavy-duty vehicles	Locomotives	TOTALS
Nox	5602,56	538,31	120,33	121,03	0,00	599,26	3,91	**6985,40**
NMVOCs	294,24	28,27	6,32					**328,83**
PM10	469,18	45,08	10,08		79,97	25,75	0,11	**630,17**
Sox	6768,37	650,33	145,37	19,79				**7583,86**
CO	3619,12	347,74	77,73	55,50				**4100,09**
PORT FORECAST 2015								
	Vessels	Tug boats	Auxiliary means	Cargo handling	Solid bulks	Heavy-duty vehicles	Locomotives	TOTALS
Nox	6255,49	600,55	138,38	84,28	0,00	493,86	26,85	**7599,42**
NMVOCs	330,26	31,71	7,31					**369,28**
PM10	351,92	33,79	7,78		53,12	21,22	0,52	**468,35**
Sox	2753,99	264,39	60,92	13,78				**3093,08**
CO	4040,90	387,94	89,39	38,65				**4556,88**
APICE								
	Vessels	Tug boats	Auxiliary means	Cargo handling	Solid bulks	Heavy-duty vehicles	Locomotives	TOTALS
Nox	5664,34	345,32	138,38	53,63		460,37	28,98	**6691,02**
NMVOCs	330,26	20,13	8,07					**358,47**
PM10	308,94	18,83	11,40		53,12	19,78	0,56	**412,64**
Sox	2459,54	149,94	6,19	5,01				**2620,68**
CO	3659,02	223,07	89,39	14,06				**3985,54**

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