
Supplementary Material of

The Italian National Air Pollution Control Programme: Air Quality, Health Impact and Cost Assessment

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S1 – Setup of the MINNI Model

For details and references, please refer to Vitali, L.; Adani, M.; Briganti, G.; Cappelletti, A.; Ciancarella, L.; Cremona, G.; D'Elia, I.; D'Isidoro, M.; Guarnieri, G.; Mircea, M.; et al. AMS-MINNI National Air Quality Simulation on Italy for the Calendar Year 2015. Annual Air Quality Simulation of MINNI Atmospheric Modelling System: Results for the Calendar Year 2015 and Comparison with Observed Data, ENEA Technical Report, RT/2019/15/ENEA, ISSN 2499-5347. Available online: <http://hdl.handle.net/20.500.12079/52259>, 2019 (accessed on 31 January 2021).

Table S1. Main characteristics of the modelling setup for the Italian NAPCP simulations.

Chemical Transport Model Simulation (FARM)	
Horizontal resolution	4 km
Vertical layers	16 terrain-following layers
Vertical extent	10000 m
First layer depth	40 m
Advection scheme	Blackman cubic polynomials
Gas-phase chemistry	SAPRC99
Secondary inorganic aerosols module	ISORROPIA v1.7
Formation of secondary organic aerosols	SORGAM module
Aerosol model	AERO3
In-cloud chemistry	Included
Boundary/Initial Conditions	EMEP-MSCW (Meteorological Synthesizing Centre-West of EMEP)
Dry deposition	Resistance model
Wet deposition	Differentiated between in-cloud and sub-cloud
Meteorological Simulation (RAMS)	
Initialisation	ECMWF analysis, SYNOP/METAR observations
Meteorological year	2010 for both base and scenario simulations
Radiative Scheme	Included
Convection Parametrisation	Modified Kuo scheme
Lower Boundary	LEAF-2, Land Ecosystem–Atmosphere Feedback model
Turbulence Closure	Mellor-Yamada level 2.5 scheme
Data Assimilation	Nudging on pre-processed re-analyses
Output archiving	Fields archived at hourly intervals
Emission Processing (EMMA)	
Anthropogenic emissions Inventories	National Emission Inventories of Italy and neighbouring countries reported to the European Monitoring and Evaluation Programme of the UNECE Convention on Long-range Transboundary Air Pollution
Anthropogenic emissions Scenarios	2030 WM and WAM elaborated by the GAINS-Italy model and downscaled to NUTS3 level
Biogenic NMVOCs and soil NO	MEGAN v2.04
Sea salt	Included
Natural dust emissions	Included
Volcanoes	Included
Forest fires	None
Saharan dust	None

S2 – Air Pollution Concentration and Mortality Rate Maps

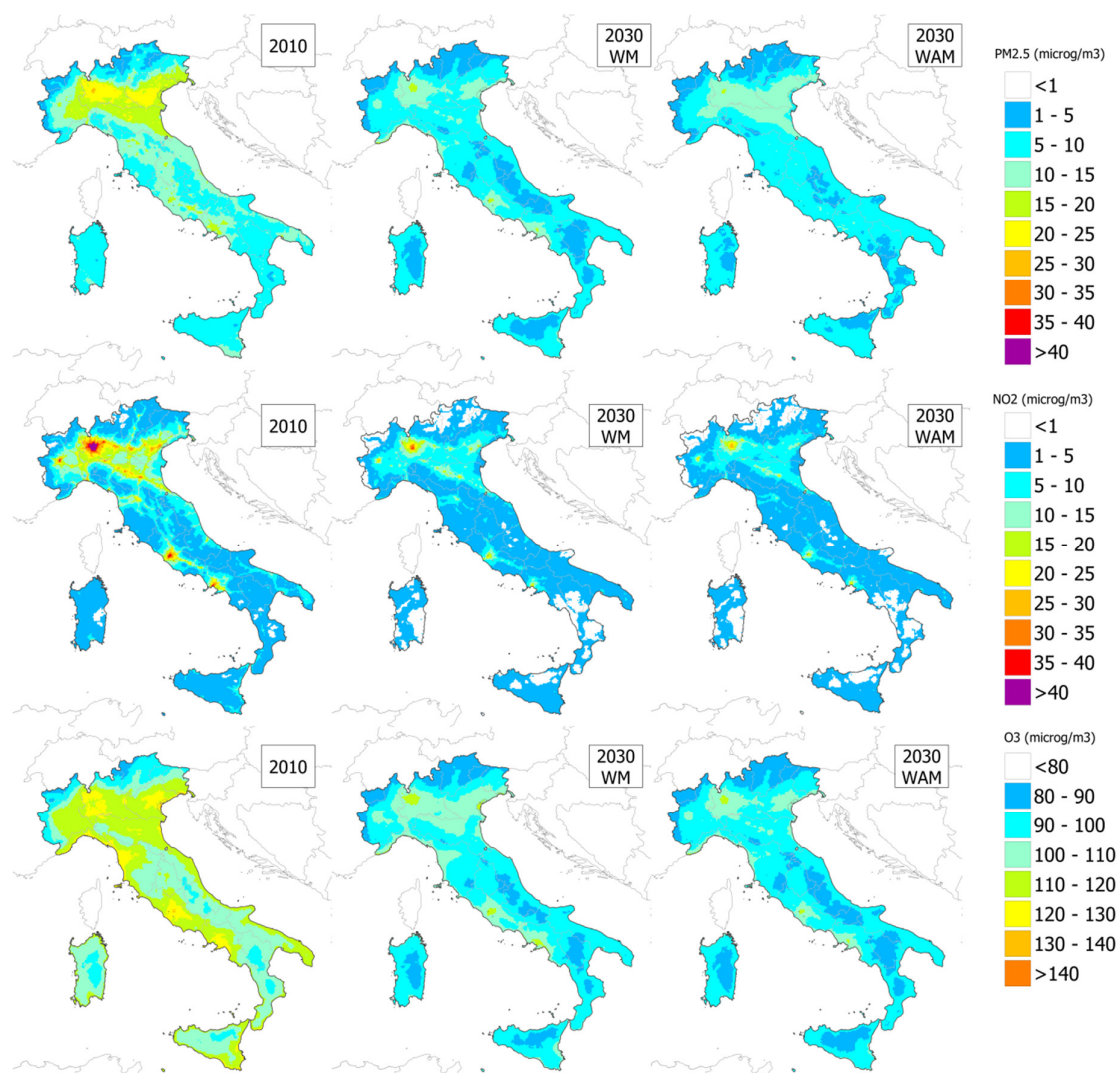


Figure S1. Annual average concentration (µg/m³) of NO₂ (upper row), PM_{2.5} (median row) and April-September average of MDA8 of O₃ (lower row), in 2010 (left column), 2030WM (central column), 2030WAM (right column).

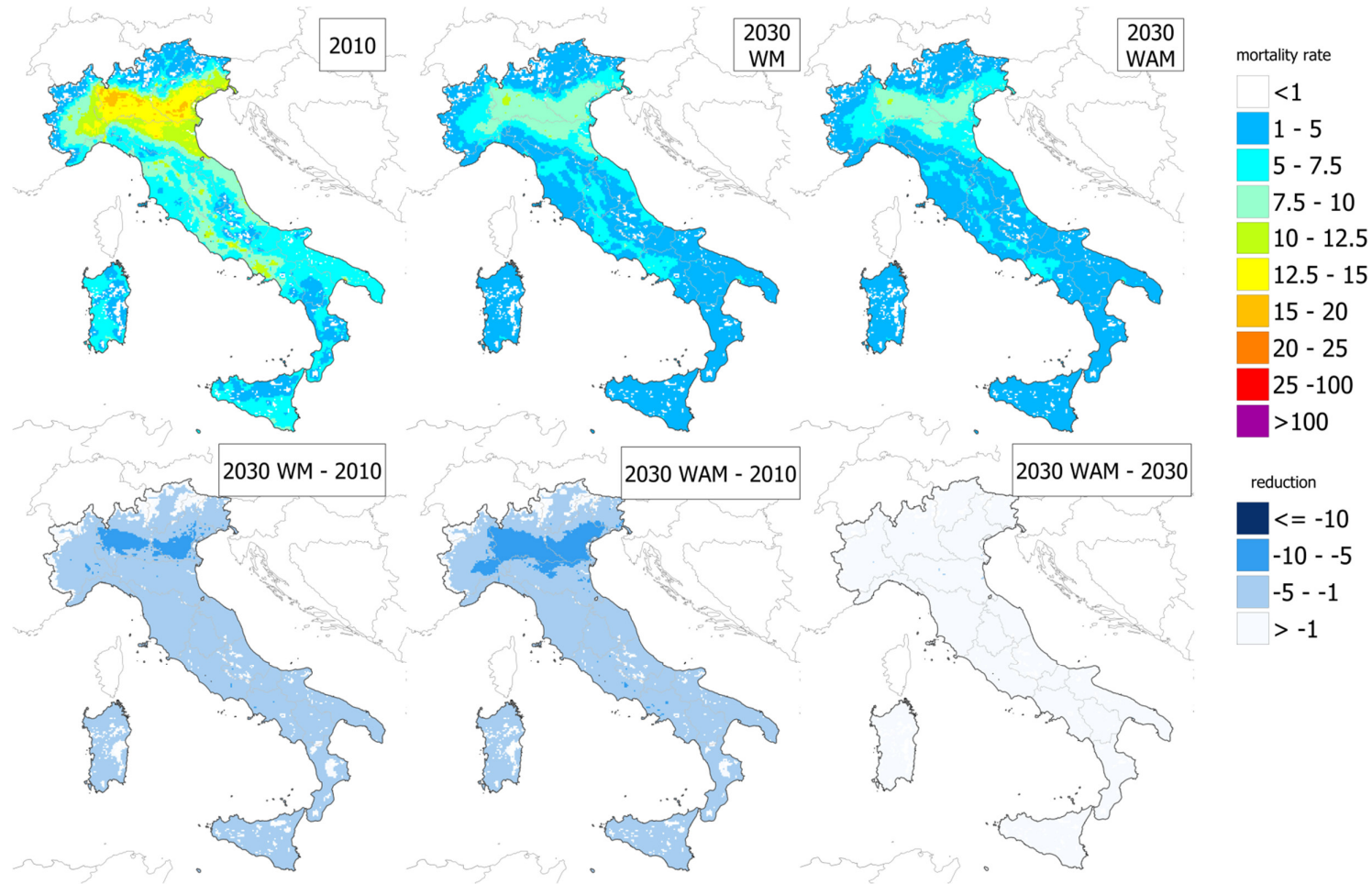


Figure S2. PM_{2.5} – Mortality rate (number of deaths per 10000 inhabitants) in 2010 (upper left), 2030WM (upper center), 2030WAM (upper right), variation in mortality rate between 2010 and 2030WM (lower left), 2010 and 2030WAM (lower center), 2030WM and 2030WAM (lower right).

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2
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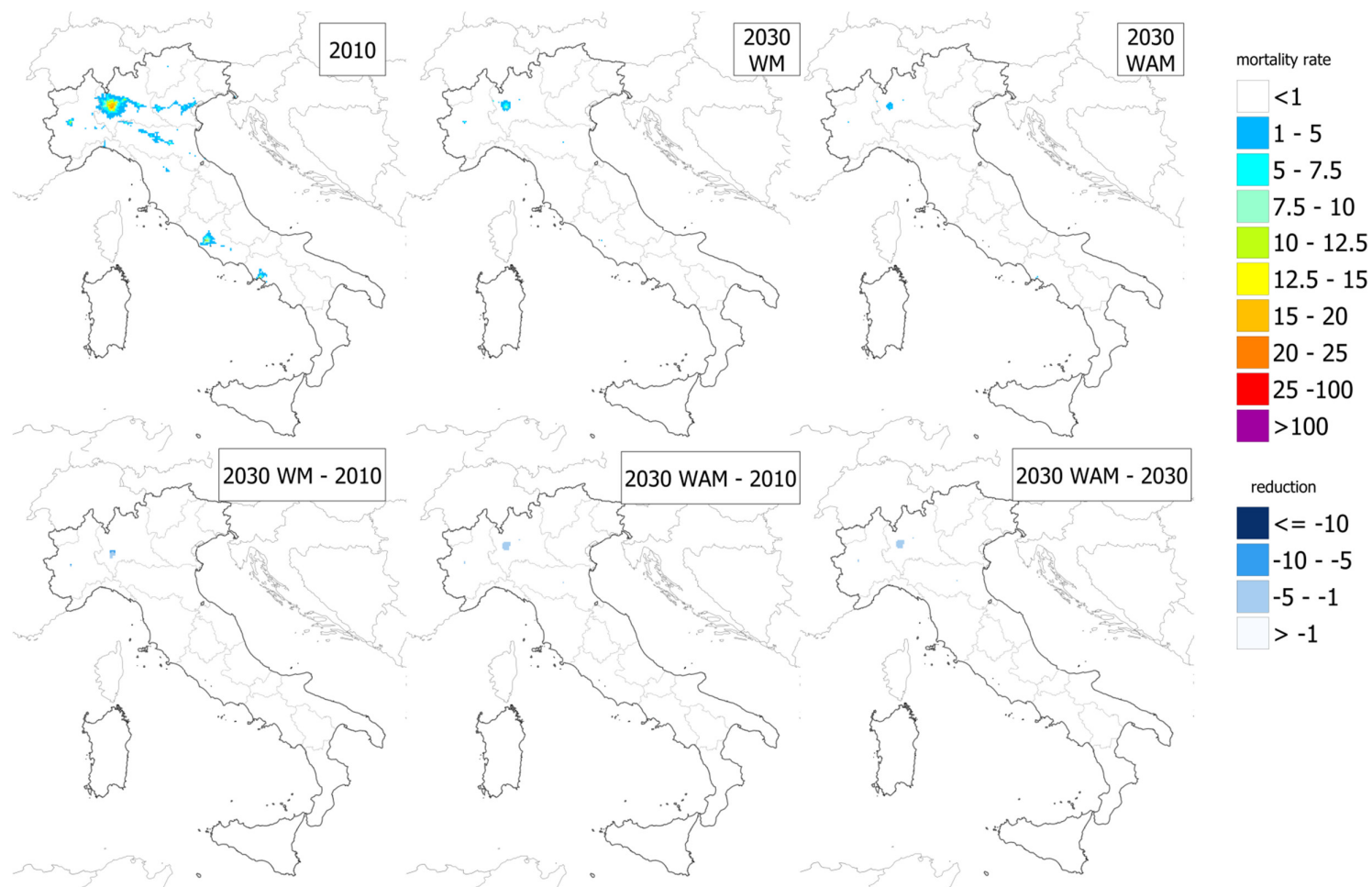


Figure S3. NO₂ – Mortality rate (number of deaths per 10000 inhabitants) in 2010 (upper left), 2030WM (upper center), 2030WAM (upper right), variation in mortality rate between 2010 and 2030WM (lower left), 2010 and 2030WAM (lower center), 2030WM and 2030WAM (lower right).

S3 – Premature Deaths and Years of Life Lost (YOLL) Attributable to PM_{2.5}, NO₂, O₃**Table S2.** – Premature deaths for all natural causes of death attributable to PM_{2.5}, NO₂ and O₃ in the base year 2010 and in the 2030 WM and WAM scenarios by Region.

REGIONS	2010 attributable cases			2030WM attributable cases		
	PM _{2.5}	NO ₂	O ₃	PM _{2.5}	NO ₂	O ₃
Abruzzo	1088 (657-1539)	0 (0-0)	52 (18-91)	680 (413-957)	0 (0-0)	31 (11-54)
Basilicata	341 (207-480)	0 (0-0)	19 (7-33)	228 (139-320)	0 (0-0)	12 (4-21)
Calabria	1084 (658-1525)	0 (0-0)	76 (27-132)	726 (442-1017)	0 (0-0)	50 (18-86)
Campania	5565 (3352-7894)	1092 (614-1593)	283 (99-495)	3476 (2108-4895)	23 (13-33)	207 (73-361)
Emilia-Romagna	5253 (3150-7483)	663 (374-964)	201 (71-352)	3454 (2087-4882)	11 (6-16)	131 (46-227)
Friuli-Venezia Giulia	1355 (814-1926)	37 (21-54)	54 (19-94)	876 (530-1237)	1 (1-1)	36 (13-63)
Lazio	5061 (3051-7171)	1873 (1050-2740)	279 (98-488)	3198 (1940-4501)	30 (17-43)	201 (71-349)
Liguria	1329 (802-1880)	135 (77-196)	86 (30-151)	832 (505-1169)	0 (0-0)	59 (21-103)
Lombardia	14202 (8473-20336)	6352 (3522-9399)	455 (160-796)	8819 (5316-12495)	1454 (818-2118)	355 (125-617)
Marche	1351 (815-1912)	0 (0-0)	68 (24-118)	847 (514-1191)	0 (0-0)	40 (14-69)
Molise	208 (126-293)	0 (0-0)	11 (4-20)	135 (82-189)	0 (0-0)	7 (2-12)
Piemonte	4350 (2618-6175)	1021 (572-1494)	181 (64-315)	2713 (1644-3822)	208 (118-302)	132 (47-228)
Puglia	2771 (1678-3908)	0 (0-0)	174 (61-304)	1802 (1096-2529)	0 (0-0)	101 (36-174)
Sardegna	1021 (619-1439)	0 (0-0)	61 (22-107)	695 (423-975)	0 (0-0)	41 (15-71)
Sicilia	2810 (1705-3954)	0 (0-0)	219 (77-383)	1878 (1144-2632)	0 (0-0)	136 (48-235)
Toscana	3132 (1890-4432)	68 (39-98)	174 (61-304)	2004 (1217-2819)	0 (0-0)	110 (39-190)
Trentino-Alto Adige	681 (412-961)	14 (8-21)	31 (11-53)	429 (261-602)	0 (0-0)	21 (7-35)
Umbria	793 (479-1124)	0 (0-0)	34 (12-59)	514 (312-724)	0 (0-0)	21 (7-36)
Valle D'Aosta	50 (30-70)	0 (0-0)	3 (1-5)	33 (20-46)	0 (0-0)	2 (1-4)
Veneto	6423 (3843-9169)	512 (289-743)	231 (81-404)	3999 (2415-5655)	0 (0-0)	158 (56-274)
ITALY	58867 (35379-83670)	11769 (6566-17301)	2692 (945-4702)	37335 (22608-52656)	1727 (972-2513)	1851 (654-3211)

2030WAM attributable cases			
REGIONS	PM _{2.5}	NO ₂	O ₃
Abruzzo	628 (382-883)	0 (0-0)	29 (10-50)
Basilicata	219 (133-307)	0 (0-0)	11 (4-20)
Calabria	695 (423-973)	0 (0-0)	46 (16-80)
Campania	3255 (1975-4580)	20 (11-29)	192 (68-334)
Emilia-Romagna	3169 (1917-4473)	4 (2-6)	123 (44-213)
Friuli-Venezia Giulia	817 (495-1152)	1 (0-1)	34 (12-58)
Lazio	2964 (1800-4168)	0 (0-0)	183 (65-318)
Liguria	760 (462-1068)	0 (0-0)	55 (19-96)
Lombardia	8115 (4899-11481)	700 (396-1015)	335 (118-581)
Marche	789 (479-1109)	0 (0-0)	37 (13-64)
Molise	127 (77-178)	0 (0-0)	6 (2-11)
Piemonte	2477 (1503-3486)	69 (39-99)	125 (44-217)
Puglia	1729 (1052-2426)	0 (0-0)	96 (34-166)
Sardegna	674 (410-946)	0 (0-0)	40 (14-68)
Sicilia	1834 (1117-2570)	0 (0-0)	125 (44-216)
Toscana	1857 (1128-2611)	0 (0-0)	101 (36-175)
Trentino-Alto Adige	398 (243-559)	0 (0-0)	20 (7-34)
Umbria	478 (290-672)	0 (0-0)	20 (7-34)
Valle D'Aosta	31 (19-43)	0 (0-0)	2 (1-3)
Veneto	3649 (2207-5154)	0 (0-0)	145 (51-251)
ITALY	34666 (21013-48840)	793 (449-1149)	1725 (610-2990)

Table S3. – Years of Life Lost (YOLL) attributable to PM_{2.5}, NO₂ and O₃ in the base year 2010 and in the 2030WM and WAM scenarios by Region.

REGIONS	2010 YOLL			2030WM YOLL		
	PM _{2.5}	NO ₂	O ₃	PM _{2.5}	NO ₂	O ₃
Abruzzo	11208 (6766-15856)	0 (0-0)	537 (189-935)	7008 (4257-9854)	0 (0-0)	323 (115-558)
Basilicata	3513 (2131-4944)	0 (0-0)	197 (70-342)	2349 (1431-3294)	0 (0-0)	124 (44-214)
Calabria	11164 (6777-15705)	0 (0-0)	783 (276-1364)	7474 (4554-10477)	0 (0-0)	513 (182-887)
Campania	57324 (34521-81305)	11250 (6325-16407)	2912 (1021-5094)	35803 (21712-50419)	236 (134-339)	2136 (753-3713)
Emilia-Romagna	54105 (32445-77071)	6827 (3849-9929)	2073 (728-3620)	35579 (21500-50285)	111 (63-161)	1350 (477-2339)
Friuli-Venezia Giulia	13953 (8381-19842)	384 (217-557)	554 (195-967)	9024 (5461-12736)	10 (6-14)	374 (132-648)
Lazio	52132 (31425-73866)	19293 (10816-28218)	2869 (1005-5023)	32937 (19983-46361)	309 (176-444)	2070 (730-3599)
Liguria	13688 (8263-19368)	1394 (789-2019)	886 (310-1554)	8566 (5202-12045)	0 (0-0)	611 (215-1063)
Lombardia	146276 (87276-209456)	65427 (36277-96809)	4691 (1646-8198)	90833 (54756-128697)	14973 (8424-21819)	3654 (1288-6354)
Marche	13911 (8394-19688)	0 (0-0)	698 (245-1218)	8721 (5295-12266)	0 (0-0)	413 (146-715)
Molise	2145 (1299-3023)	0 (0-0)	117 (41-203)	1385 (843-1944)	0 (0-0)	69 (25-120)
Piemonte	44808 (26964-63601)	10517 (5895-15385)	1864 (656-3249)	27939 (16934-39365)	2145 (1213-3112)	1357 (480-2351)
Puglia	28545 (17288-40251)	0 (0-0)	1797 (632-3134)	18559 (11291-26050)	0 (0-0)	1039 (369-1796)
Sardegna	10517 (6374-14819)	0 (0-0)	631 (222-1097)	7156 (4355-10043)	0 (0-0)	426 (151-736)
Sicilia	28942 (17567-40721)	0 (0-0)	2258 (793-3942)	19340 (11781-27109)	0 (0-0)	1399 (496-2422)
Toscana	32256 (19465-45651)	700 (398-1010)	1788 (627-3127)	20642 (12531-29037)	0 (0-0)	1130 (400-1959)
Trentino-Alto Adige	7013 (4244-9898)	147 (83-212)	316 (112-547)	4416 (2686-6199)	0 (0-0)	211 (75-365)
Umbria	8173 (4930-11573)	0 (0-0)	350 (123-608)	5298 (3215-7457)	0 (0-0)	218 (77-376)
Valle D'Aosta	511 (311-717)	0 (0-0)	27 (10-47)	338 (206-473)	0 (0-0)	21 (8-37)
Veneto	66152 (39583-94445)	5277 (2981-7658)	2380 (835-4160)	41187 (24874-58245)	0 (0-0)	1625 (574-2820)
ITALY	606335 (364405-861802)	121216 (67631-178203)	27725 (9736-48430)	384556 (232867-542354)	17784 (10016-25889)	19065 (6737-33071)
2030WAM YOLL						
REGIONS	PM _{2.5}	NO ₂	O ₃			
Abruzzo	6473 (3935-9093)		0 (0-0)		300 (106-518)	
Basilicata	2256 (1375-3163)		0 (0-0)		117 (41-201)	
Calabria	7155 (4360-10026)		0 (0-0)		476 (169-822)	
Campania	33524 (20345-47174)		208 (118-299)		1982 (700-3441)	
Emilia-Romagna	32642 (19750-46074)		41 (23-58)		1270 (450-2199)	
Friuli-Venezia Giulia	8414 (5096-11863)		5 (3-8)		347 (123-601)	
Lazio	30526 (18536-42931)		0 (0-0)		1889 (667-3280)	
Liguria	7833 (4761-11004)		0 (0-0)		569 (201-989)	
Lombardia	83584 (50456-118259)		7210 (4076-10455)		3447 (1217-5988)	
Marche	8125 (4937-11420)		0 (0-0)		381 (135-658)	
Molise	1310 (798-1838)		0 (0-0)		64 (23-110)	
Piemonte	25515 (15481-35911)		706 (401-1019)		1289 (456-2232)	
Puglia	17805 (10836-24983)		0 (0-0)		988 (351-1707)	
Sardegna	6942 (4225-9739)		0 (0-0)		408 (145-705)	
Sicilia	18890 (11509-26474)		0 (0-0)		1287 (456-2225)	
Toscana	19132 (11623-26891)		0 (0-0)		1039 (368-1799)	
Trentino-Alto Adige	4104 (2498-5757)		0 (0-0)		202 (72-349)	

Umbria	4924 (2990-6924)	0 (0-0)	203 (72-350)
Valle D'Aosta	315 (192-440)	0 (0-0)	21 (7-36)
Veneto	37590 (22733-53084)	0 (0-0)	1493 (528-2587)
ITALY	357058 (216436-503048)	8169 (4621-11839)	17772 (6286-30795)

Table S4. Total and per pollutant damage-costs (mln €) of the base year 2010.

REGIONS	2010			
	PM _{2.5} costs (mln €)	NO ₂ costs (mln €)	O ₃ costs (mln €)	TOT costs (mln €)
Abruzzo	889 (537-1258)	0 (0-0)	43 (15-74)	932 (552-1332)
Basilicata	235 (143-331)	0 (0-0)	13 (5-23)	248 (147-354)
Calabria	683 (415-961)	0 (0-0)	48 (17-83)	731 (431-1044)
Campania	3652 (2199-5180)	717 (403-1045)	185 (65-325)	4554 (2667-6549)
Emilia-Romagna	5454 (3271-7769)	688 (388-1001)	209 (73-365)	6351 (3732-9135)
Friuli-Venezia Giulia	1297 (779-1845)	36 (20-52)	52 (18-90)	1385 (818-1987)
Lazio	5568 (3356-7889)	2061 (1155-3014)	306 (107-537)	7935 (4619-11440)
Liguria	1286 (776-1820)	131 (74-190)	83 (29-146)	1501 (880-2156)
Lombardia	16313 (9733-23359)	7296 (4046-10796)	523 (184-914)	24132 (13962-35069)
Marche	1183 (714-1674)	0 (0-0)	59 (21-104)	1242 (735-1778)
Molise	156 (95-221)	0 (0-0)	9 (3-15)	165 (98-235)
Piemonte	4145 (2495-5884)	973 (545-1423)	172 (61-301)	5291 (3101-7608)
Puglia	1772 (1073-2498)	0 (0-0)	112 (39-195)	1883 (1112-2693)
Sardegna	738 (447-1040)	0 (0-0)	44 (16-77)	782 (463-1117)
Sicilia	1835 (1114-2582)	0 (0-0)	143 (50-250)	1978 (1164-2832)
Toscana	3009 (1816-4259)	65 (37-94)	167 (59-292)	3241 (1912-4645)
Trentino-Alto Adige	461 (279-650)	10 (5-14)	21 (7-36)	491 (292-700)
Umbria	679 (410-962)	0 (0-0)	29 (10-51)	709 (420-1013)
Valle D'Aosta	60 (36-84)	0 (0-0)	3 (1-5)	63 (37-89)
Veneto	6284 (3760-8971)	501 (283-727)	226 (79-395)	7011 (4122-10094)
ITALY	53921 (32406-76640)	10780 (6014-15848)	2466 (866-4307)	67167 (39287-96794)

Table S5. Total and per pollutant benefit-costs (mln €) of the 2030WM scenario, compared to the base year 2010, and of the 2030WAM scenario, compared to the 2030WM.

REGIONS	Benefits 2030 WM vs 2010				Benefits 2030 WAM vs WM			
	PM _{2.5} (mln €)	NO ₂ (mln €)	O ₃ (mln €)	TOTAL (mln €)	PM _{2.5} (mln €)	NO ₂ (mln €)	O ₃ (mln €)	TOTAL (mln €)
Abruzzo	333 (199-476)	0 (0-0)	17 (6-30)	350 (205-506)	43 (26-60)	0 (0-0)	2 (1-3)	44 (26-64)
Basilicata	78 (47-110)	0 (0-0)	5 (2-9)	83 (49-119)	6 (4-9)	0 (0-0)	1 (0-1)	7 (4-10)
Calabria	226 (136-320)	0 (0-0)	17 (6-29)	242 (142-349)	20 (12-28)	0 (0-0)	2 (1-4)	22 (13-32)
Campania	1371 (816-1968)	702 (394-1024)	49 (17-88)	2122 (1227-3079)	145 (87-207)	2 (1-3)	10 (3-17)	157 (92-227)
Emi- lia-Romagna	1867 (1103-2700)	677 (382-985)	73 (25-129)	2617 (1510-3814)	296 (176-424)	7 (4-10)	8 (3-14)	311 (183-449)
Friuli-Venezia Giulia	458 (272-661)	35 (20-50)	17 (6-30)	510 (297-741)	57 (34-81)	0 (0-1)	3 (1-4)	60 (35-86)
Lazio	2050 (1222-2938)	2028 (1137-2966)	85 (29-152)	4163 (2388-6056)	258 (155-366)	33 (19-47)	19 (7-34)	310 (180-448)
Liguria	481 (288-688)	131 (74-190)	26 (9-46)	638 (371-924)	69 (41-98)	0 (0-0)	4 (1-7)	73 (43-105)
Lombardia	6183 (3627-9006)	5627 (3106-8363)	116 (40-206)	11925 (6773-17575)	808 (480-1164)	866 (485-1267)	23 (8-41)	1697 (973-2472)
Marche	441 (263-631)	0 (0-0)	24 (8-43)	465 (272-674)	51 (30-72)	0 (0-0)	3 (1-5)	53 (31-77)
Molise	55 (33-79)	0 (0-0)	3 (1-6)	59 (35-85)	5 (3-8)	0 (0-0)	0 (0-1)	6 (3-8)
Piemonte	1561 (928-2242)	775 (433-1135)	47 (16-83)	2382 (1377-3461)	224 (134-320)	133 (75-194)	6 (2-11)	364 (212-524)
Puglia	620 (372-881)	0 (0-0)	47 (16-83)	667 (389-964)	47 (28-66)	0 (0-0)	3 (1-6)	50 (29-72)
Sardegna	236 (142-335)	0 (0-0)	14 (5-25)	250 (147-361)	15 (9-21)	0 (0-0)	1 (0-2)	16 (10-24)
Sicilia	609 (367-863)	0 (0-0)	54 (19-96)	663 (386-960)	29 (17-40)	0 (0-0)	7 (2-13)	36 (20-53)
Toscana	1083 (647-1550)	65 (37-94)	61 (21-109)	1210 (705-1753)	141 (85-200)	0 (0-0)	8 (3-15)	149 (88-215)
Trentino-Alto Adige	171 (102-243)	10 (5-14)	7 (2-12)	187 (110-269)	21 (12-29)	0 (0-0)	1 (0-1)	21 (13-30)
Umbria	239 (143-342)	0 (0-0)	11 (4-19)	250 (146-362)	31 (19-44)	0 (0-0)	1 (0-2)	32 (19-46)
Valle D'Aosta	20 (12-28)	0 (0-0)	1 (0-1)	21 (12-30)	3 (2-4)	0 (0-0)	0 (0-0)	3 (2-4)
Veneto	2371 (1397-3439)	501 (283-727)	72 (25-127)	2944 (1705-4293)	342 (203-490)	0 (0-0)	13 (4-22)	354 (208-512)
ITALY	19723 (11698-28408)	9198 (5124-13545)	770 (267-1366)	29691 (17088-43320)	2445 (1461-3495)	855 (480-1249)	115 (40-202)	3415 (1981-4947)