Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Sorgenti di particolati fini e ultrafini: attività integrate per lo studio dell'esposizione della popolazione

Aria & Salute Il futuro della Ricerca e l'Innovazione Sostenibile

Università di Milano-Bicocca

29 Novembre 2017

Maurizio Gualtieri SSPT-MET-INAT

What we know about air pollution and health effects

Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution

Epidemiological Evidence of General Pathophysiological Pathways of Disease

Particulate matter and atherosclerosis: role of particle size, composition and oxidative stress

The carcinogenicity of outdoor air pollution

The IARC Working Group unanimously classified outdoor air pollution and particulate matter from outdoor air pollution as carcinogenic to humans (IARC Group 1), based on sufficient evidence of carcinogenicity in humans and experimental animals and strong mechanistic evidence.

Associations of acute exposure to fine and coarse particulate matter and mortality among older people in Tokyo, Japan

Particulate matter exposure is associated with inflammatory gene methylation in obese subjects

Fine Particulate Matter ($PM_{2.5}$) and the Risk of Stroke in the REGARDS Cohort

Toxicity of inhaled particulate matter on the central nervous system: neuroinflammation, neuropsychological effects and neurodegenerative disease

Air Pollution: Mechanisms of Neuroinflammation & CNS Disease

What we know about air pollution and health effects

The Ostrava declaration

In the WHO European Region, environmental factors that could be avoided and/or eliminated cause 1.4 million deaths per year. The major health impacts of environmental determinants in the Region are related to noncommunicable diseases, disabilities and unintentional injuries, with

What we know about air pollution and health effects

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1. *Recognize* that the 2030 Agenda for Sustainable Development highlights critical and inseparable links between development, environment, human health and well-being, and the economy as central to the attainment of a wide range of human rights, including: the rights to life; the enjoyment of the highest attainable standard of physical and mental health; an adequate standard of living; safe food, drinking-water and sanitation; safety; and clean soil, waters and air, which are key to promoting just, peaceful, inclusive and prosperous societies today and in the future;

Air pollution in number

The Ostrava declaration

Every year, ambient (outdoor) air pollution causes nearly 500 000 premature deaths in the Region. Household (indoor) air pollution from solid fuel combustion for heating and cooking is responsible for nearly 120 000 premature deaths in the Region and a disproportionate disease burden in certain regions and less affluent parts of society, thus increasing inequalities. WHO estimated that the economic cost of the health impact of air pollution was US$ 1.6 trillion in 2010.

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In European cities that monitor air pollution (1791 cities in 42 countries), annual urban levels of particulate matter with a diameter of 10 micrometres or less (PM10) generally exceed the WHO guidelines value (mean annual level of 20 $\mu g/m^3$). The average annual level in cities in European high-income countries is 25 $\mu g/m^3$, whereas it is 55 $\mu g/m^3$ in cities in European low- and middle-income countries.

Environmental equity

The Ostrava declaration

We therefore resolve:

to protect and promote the health and well-being of all our people and to prevent premature deaths, diseases and inequalities related to environmental pollution and degradation;

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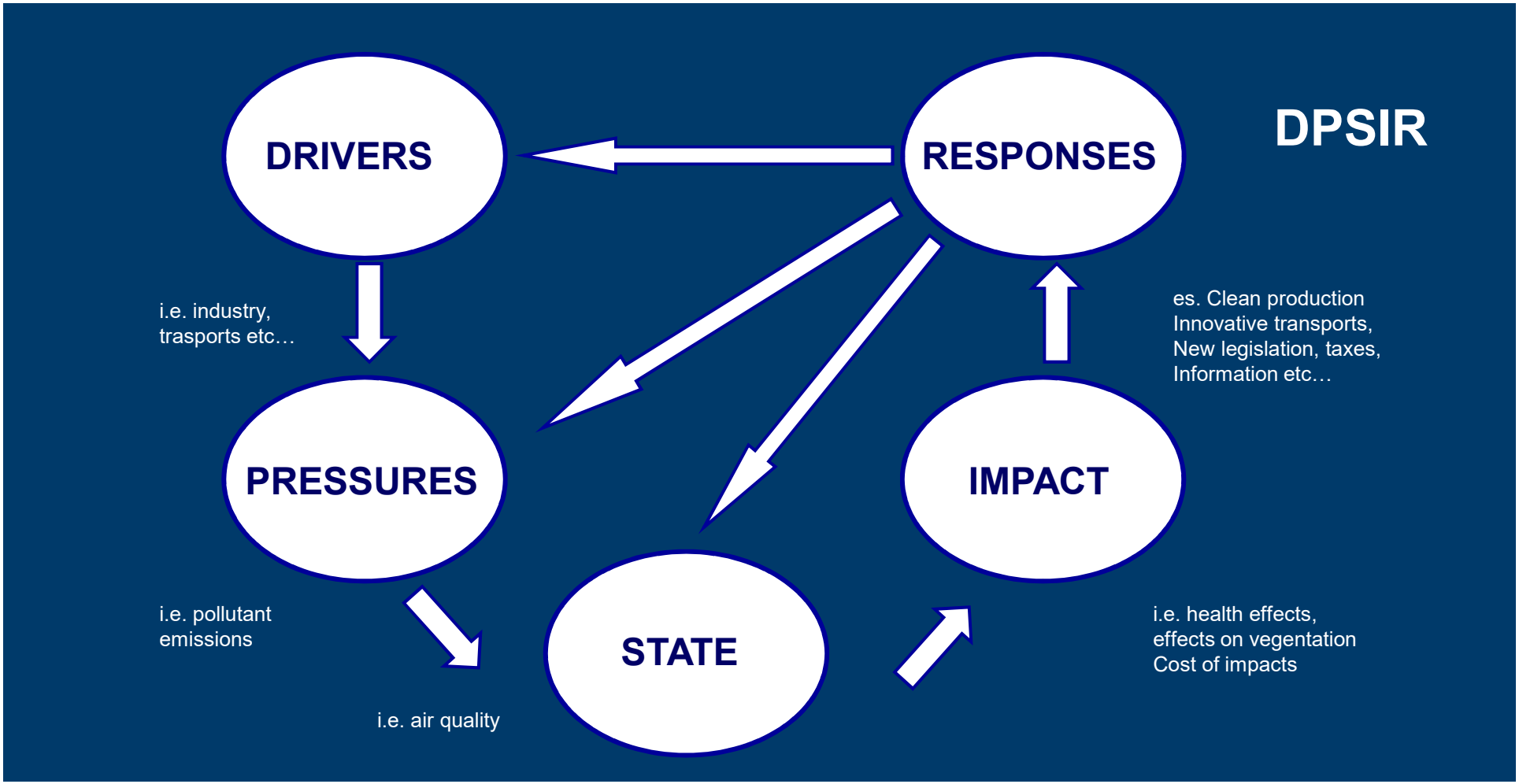
improving indoor and outdoor air quality for all, as one of the most important environmental risk factors in the Region, through actions to meet the values of the WHO air quality guidelines in a continuous process of improvement;


DRIVERS
RESPONSES
DPSIR
i.e. industry,
trasports etc…
es. Clean production
Innovative transports,
New legislation, taxes,
Information etc…
PRESSURES
IMPACT
i.e. pollutant
emissions
STATE
i.e. health effects,
effects on vegentation
Cost of impacts
i.e. air quality

Environmental equity

How to define air pollutants concentration

- Modelling simulations
- Experimental approaches

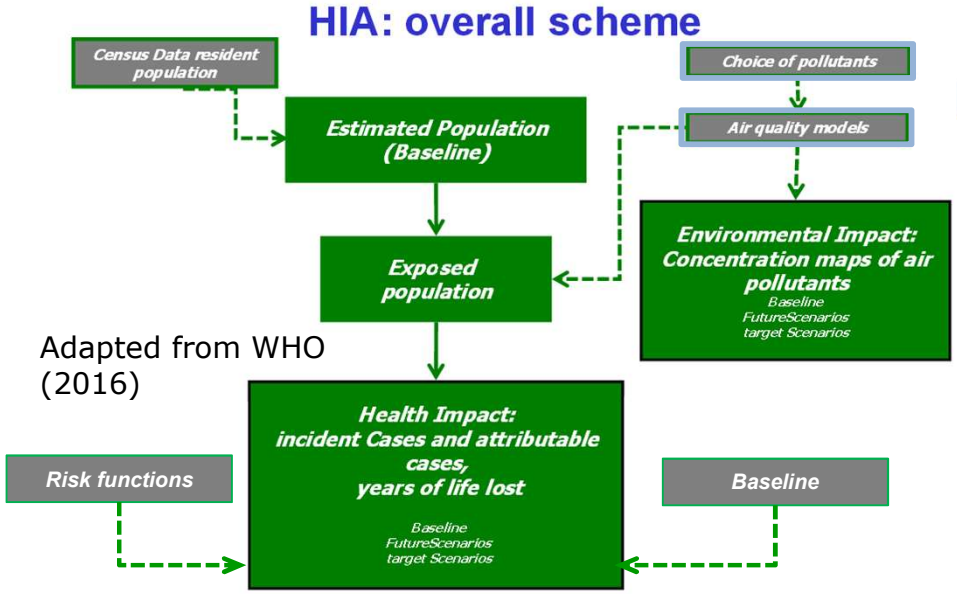
…and expected exposure and impacts population

- Relative risk (epidemiological evidences)
- Toxicological evaluation

Modelling simulations

VIIAS project

(Integrated Assessment of the Impact of Air Pollution on the Environment and Health)



Adapted from WHO (2016)

www.minni.org

National air quality model

Modelled years:

Baseline
- 2005 and 2010

Future scenarios
- 2020 Current Legislation (**CLE**)

2020 with different scenarios
- **T1:** compliance with EU and Italian air quality standards
- **T2**: -20% CLE concentration

Modelled pollutants:

NO_2
PM2.5
PM10
Ozono

Annual mean

SOMO10
SOMO 35

Modello **I**ntegrato **N**azionale a supporto della **N**egoziazione **I**nternazionale sui temi dell'inquinamento atmosferico

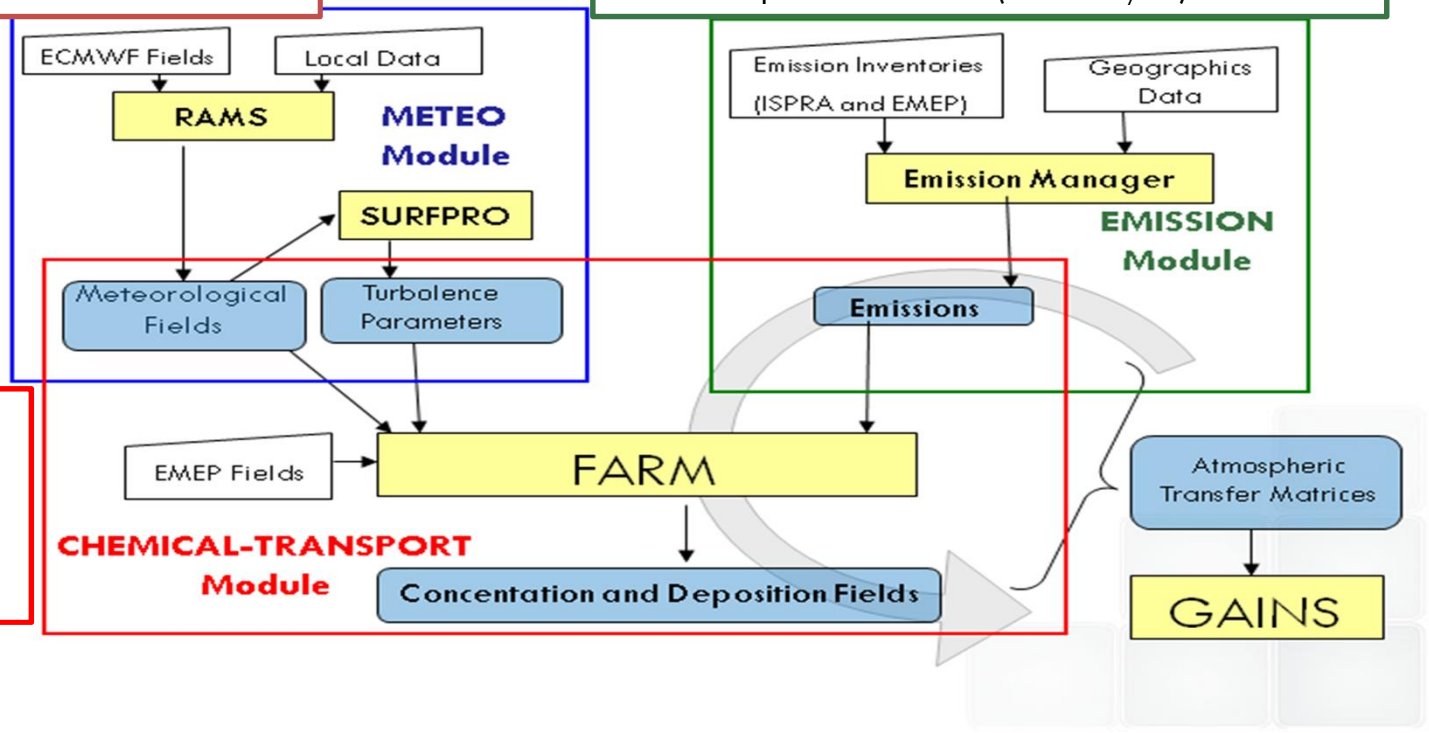
http://www.minni.org/

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

ARIANET

RAMS (METEOROLOGICAL MODEL)
- prognostic non-hydrostatic
- open source http://www.atmet.com/index.shtml
- compiled in its parallel version
- implemented in MVAPICH environment

EMISSION MANAGER (EMISSION PRE-PROCESSOR)
- Modular pre-processing system for model-ready emissions input (Spray, Chimere FARM)
- different geometries treatment (point, area, line)
- different speciation schemes (SAPRC90/99)



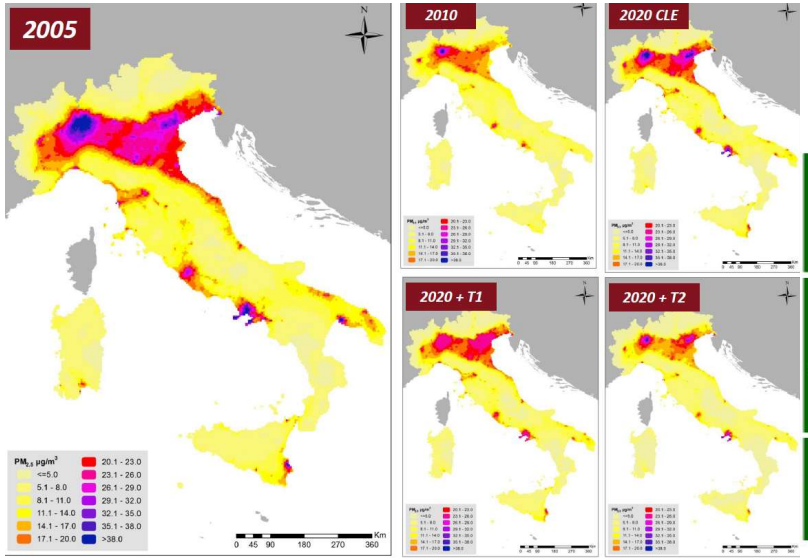
FARM (CHEMICAL TRANSPORT MODEL)
- 3D Eulerian grid dispersion model
- K-closure turbulence
- SAPRC90/99 chemical mechanisms
- AERO3 aerosol model
- OpenMP compiler directives

ENEA

Modelling simulations

VIIAS project

- Air quality simulations of $PM_{2.5}$
- Exposed population

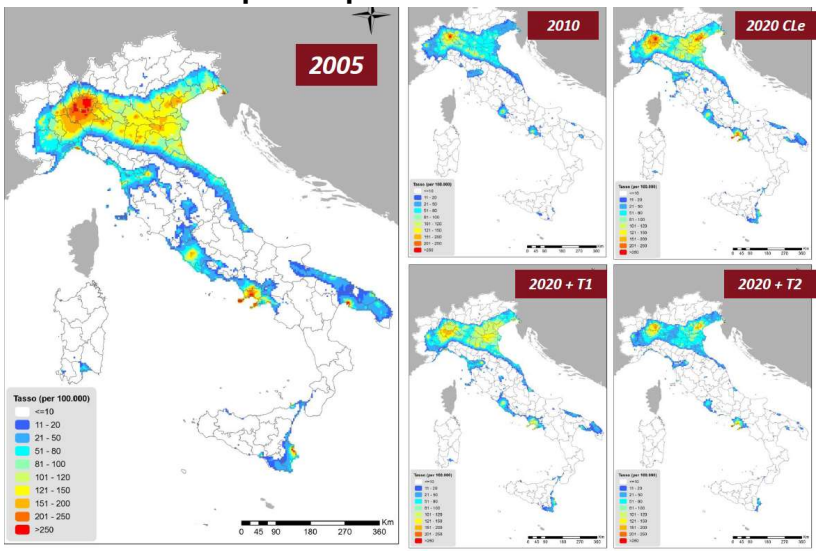


		≤10		10-25		>25		Totale	
		N	%	N	%	N	%	N	%
ITALIA		11.139.673	19,1	30.157.156	51,8	16.907.745	29,0	58.204.574	100,0
Area geografica	NORD	2.636.654	10,0	12.679.794	48,0	11.084.442	42,0	26.400.890	100,0
	CENTRO	1.692.911	13,5	8.645.375	69,0	2.187.111	17,5	12.525.398	100,0
	SUD e ISOLE	6.810.108	35,3	8.831.987	45,8	3.636.192	18,9	19.278.286	100,0
Macroarea	URBANO	837.584	4,1	8.811.988	42,8	10.957.053	53,2	20.606.625	100,0
	NON URBANO	10.302.088	27,4	21.345.168	56,8	5.950.692	15,8	37.597.948	100,0

Modelling simulations

VIIAS project

- Health impact prediction



Death rates attributable to **$PM_{2.5}$** each 100000 inhabitants

			2005	2010	2020 CLE	2020 CLE - Target1	2020 CLE - Target2
PM2.5	general mortality	population exposure (µg/m³)	20.1	15.8	18.1	16.2	14.5
		attributable deaths (95% confidence interval)	34552 (20608-43215)	21524	28595	23170	18511
		months of life lost	9.7	5.5	7.7	5.9	4.2
NO_2	general mortality	population exposure (µg/m³)	24.7	17.9	16.6	16.1	13.3
		attributable deaths (95% confidence interval)	23387 (21514-50283)	11993	10117	9021	5247
O_3	mortality for respiratory diseases	population exposure (µg/m³)	105.1	108.2	97	-	-
		attributable deaths (95% confidence interval)	1707 (622-2861)	1858	1320	-	-

Modelling simulations

Modelling for impact surveillance

- EU LIFE+ Pilot project, 2013-2016, 790 m€ funding by EC
- 4 countries: Italy, France, Slovenia and Spain - 7 partners (national and regional env. agencies and epidemiological surveillance agencies, 1 university)
- **Objective**: to set up a **low-cost surveillance system** of long term effects of air pollution, **based on routine air quality and health data** (National Health Interview Surveys, mortality and hospital admissions registries, air pollution models)
- pollutants: PM10, PM2.5, NO_2, O_3

Modelling simulations

Modelling for impact surveillance

MED HISS

Risks (HR) of Mortality among the Italian cohort during the follow-up (2000-2012): 75,900 subjects aged 35 or older. Risks for 10 µg/m³ increase of NO_2 and PM2.5 and 95% Confidence Interval. Significant results in bold.*

Mortality cause	Number of events	PM2.5 HR for 10 µg/m³ increase of pollutant	NO_2 HR for 10 µg/m³ increase of pollutant
Natural causes	14,166	**1.04 (1.02-1.06)**	**1.03 (1.01-1.05)**
Circulatory system diseases	5,908	**1.03 (1.00-1.06)**	**1.01 (0.98-1.04)**
Heart diseases	3,970	1.03 (0.99-1.07)	1.01 (0.98-1.05)
Cerebrovascular diseases	1,642	1.00 (0.94-1.07)	1.00 (0.94-1.06)
Respiratory system diseases	934	1.04 (0.96-1.13)	1.03 (0.95-1.11)
All cancers (but lung)	3,685	**1.06 (1.02-1.10)**	**1.04 (1.00-1.08)**
Lung cancer	851	**1.12 (1.04-1.21)**	**1.13 (1.06-1.22)**
Nervous system diseases	465	1.03 (0.93-1.15)	1.01 (0.92-1.12)
Alzheimer's disease	257	1.03 (0.89-1.20)	0.99 (0.86-1.14)

* adjusted for age, gender, educational level, activity status, living alone, BMI, smoking, physical activity.

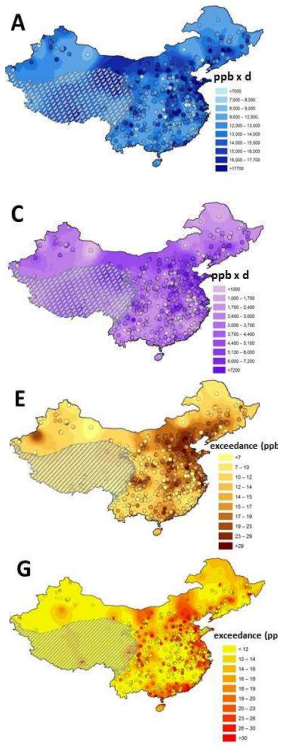
WHO:
1.06 (1.04-1.09)

Our low-cost approach is in line with the data obtained from epidemiological analyses

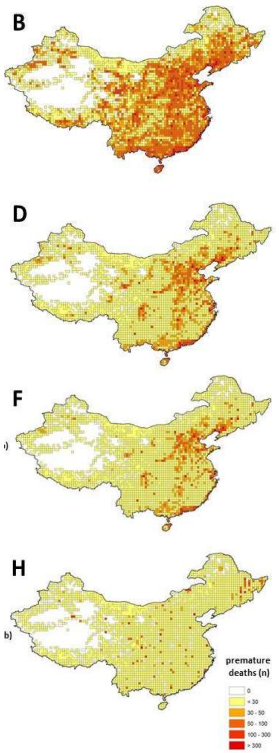
Impact assessment from monitoring data

Impact of O_3

From monitoring O_3 data (2015) to spatial distribution of ozone exceedances considering four thresholds (no threshold – A, 35 ppb EU limit – C, 50 ppb WHO limit – E and 80 ppb – G)



From spatial distribution of ozone to spatial distribution of expected premature deaths (no threshold – B, 35 ppb EU limit – D, 50 ppb WHO limit – F and 80 ppb – H)



O_3 metric	Expected number of premature deaths (min – max)	Costs (min max)
SOMO0	152,938 (50,638 - 204,603)	15.36 (4.28 – 22.02)
SOMO35	74,316 (24,699 - 99,233)	7.46 (2.09 – 10.68)
WHO (50 ppb)	59,844 (19,903 - 79,883)	6.01 (1.68 – 8.60)
China (80 ppb)	28,367 (9,450 – 37,834)	2.85 (0.8 – 4.07)

From premature deaths to impact costs quantification

Manuscript in preparation

Experimental activities

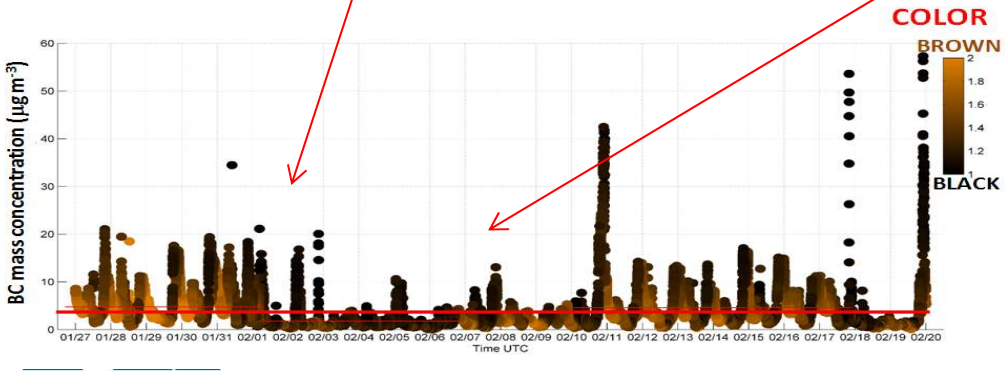
A case study in Rome

What does determine the health effects associated to fine and ultrafine PM?

1. *High concentrations,*
2. *Brown carbon,*
3. *Bigger particles*

or

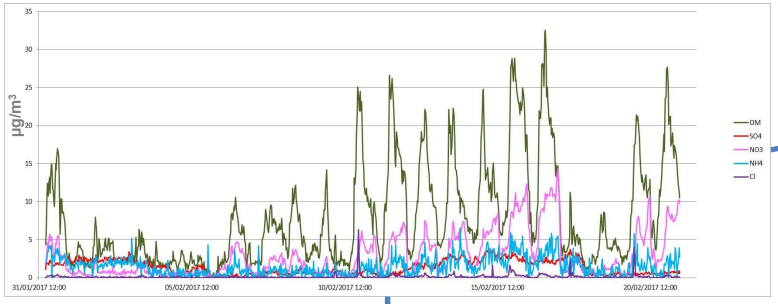
1. *Lower concentrations,*
2. *Black carbon,*
3. *Smaller particles*



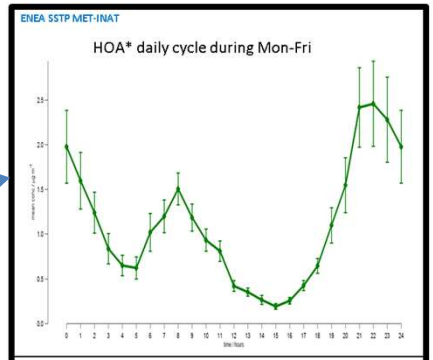
Experimental activities

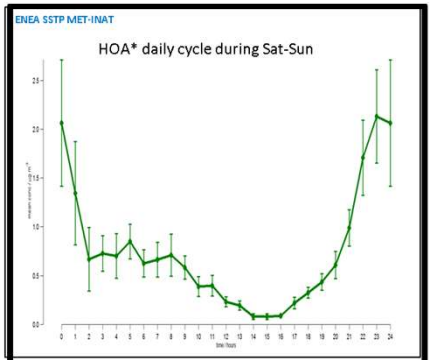
Online monitor and source identification

Aerosol Chemical Speciation Monitor (ACSM)

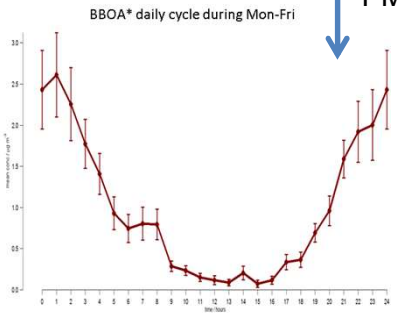


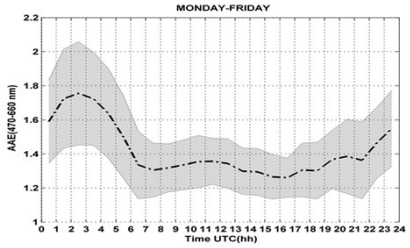
PMF

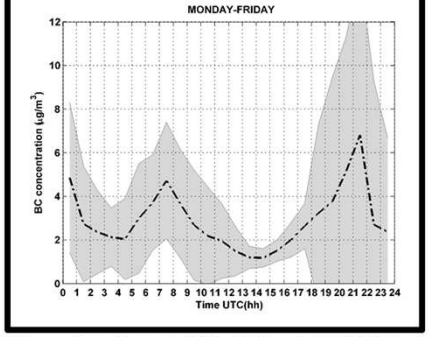


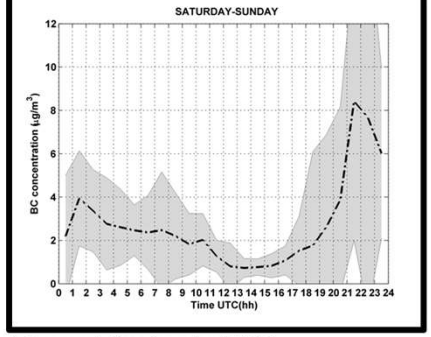


PMF







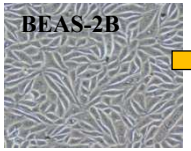


*OM Source Apportionment (PMF – ME2) analysis: HOA factor (traffic emission assoc.); time-stamp: local UTC+1

Experimental activities

Innovative exposure systems

Cell type selection

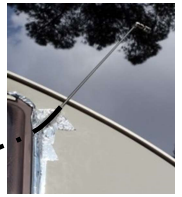


ALI culture

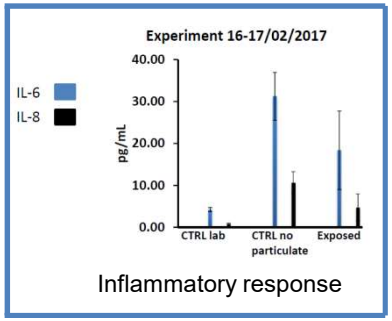
From the lab bench to….

Parallel characterization of air pollution with monitors

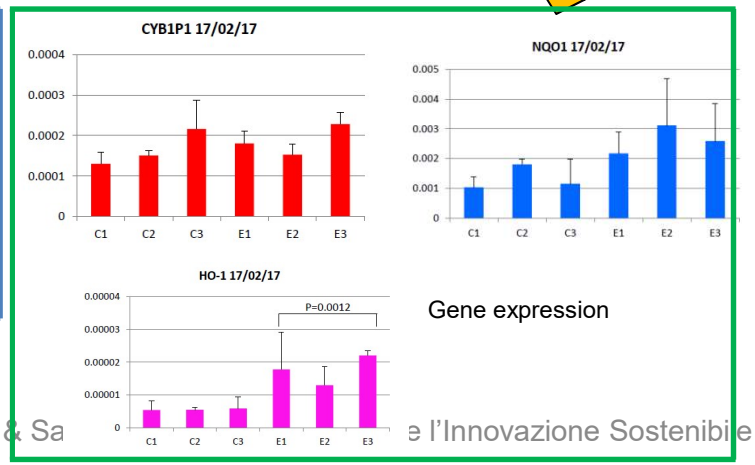
Environmental exposure



Evaluation of biological effects



Inflammatory response



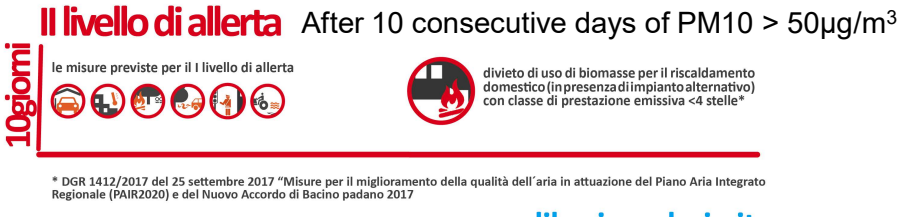
Gene expression

A step forward toward health protection

From ex-post action to exposure prevention

- Po valley basin agreement:
  - Structural actions (increase of alternative fuels, sustainable mobility, biomass burning, emission reduction from agricultural activities)

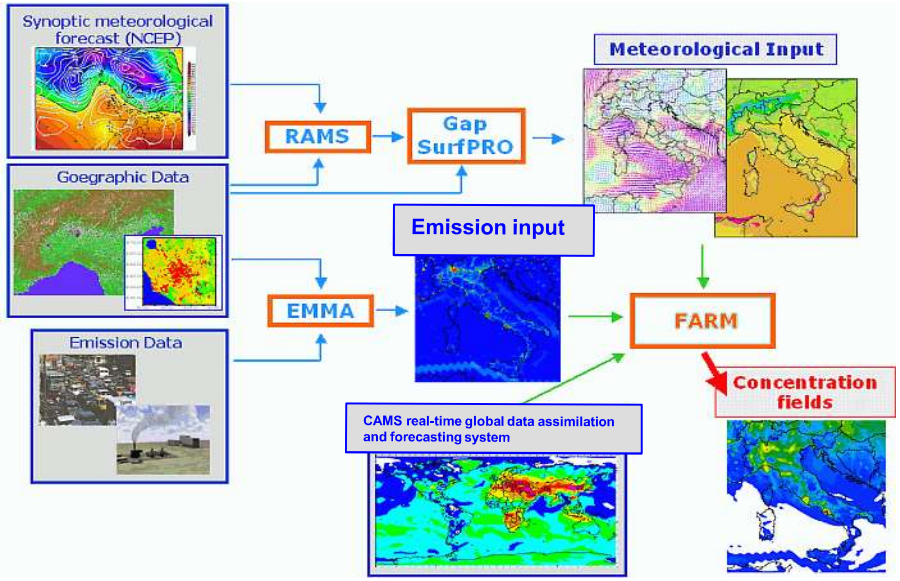
  - Emergency actions ex post if:



A step forward toward health protection

From ex-post action to exposure prevention

- ENEA air quality forecast



ENEAGRID/CRESCO, an integrated computational infrastructure (~140 Tflops)

A step forward toward health protection

From ex-post action to **exposure prevention**

- ENEA air quality forecast

http://www.afs.enea.it/project/ha_forecast/index.html
http://www.afs.enea.it/project/ha_forecast/forecast3/stats_it.html

- … and the possibility to develop tools to inform population about forecasted air pollution and possible associated health effects

Conclusion

> ENEA is working both by modelling approaches and experimental ones, integrated with epidemiological and toxicological analyses to define the expected impact of air pollution on human health

> Modelling systems may provide useful scenario of air pollution to evaluate the impact of structural action of future concentration of selected pollutants

> Experimental activities (high resolution characterization of PM, related sources and environmental toxicological effects) may provide innovative insight on the mode of action of air pollution on exposed population

> Forecast models may promote the prevention of undesired exposure and to activate preventive action.

All this is possible thank to SSPT-MET-INAT

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SSPT-TECS-BIORISC

THANK YOU

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Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Sources of fine and ultrafine PM: integrated activities for human exposure evaluation

Aria & Salute Il futuro della Ricerca e l'Innovazione Sostenibile
Università di Milano-Bicocca
29 Novembre 2017

Maurizio Gualtieri SSPT-MET-INAT