Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

“On the integration of tools to analyse the pollution-climate and health nexus”

ENERO 30th Anniversary
Bruxelles, 1st June 2022

Ilaria D’Elia, ENEA – Air Pollution Laboratory

Why this talk?

Let's start with a video from the World Meteorological Organization (WMO, World Meteorological Organization | (wmo.int))

https://youtu.be/s4ly6o-VT90

Air Pollution and Climate Change are closely interlinked

At international level

- Take «one atmosphere approach».
- Promote an integrated approach to environmental policymaking, recognizing that air pollution is the central link in the interaction between ground-level ozone, nitrogen, human health, climate change and ecosystems.
- Understand how these climate change and air pollution impact sectoral economic activities in different regions, how these impacts propagate through the economic system, and how both issues interact in their economic consequences.

Air Pollution and Climate Change are closely interlinked

At international level

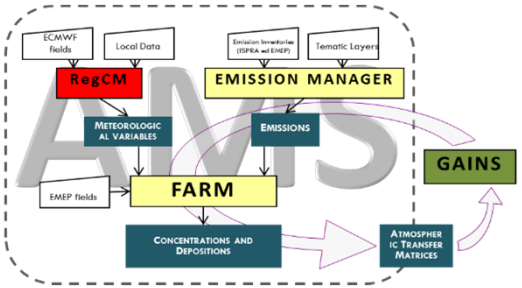
- Adequate ongoing long-term monitoring of concentrations and deposition fluxes to assess exposure and impacts on health, ecosystems, vegetation, materials and climate.
- Monitoring activities to improve the understanding of chemical and physical processes relevant
    - to assessing the effects of air pollutants on ecosystems, human health, materials and climate;
    - to support the development of cost-effective abatement strategies;
    - to support, in an integrated way, information needs associated with coupling between atmospheric composition and deposition rates with the climate system and its variability

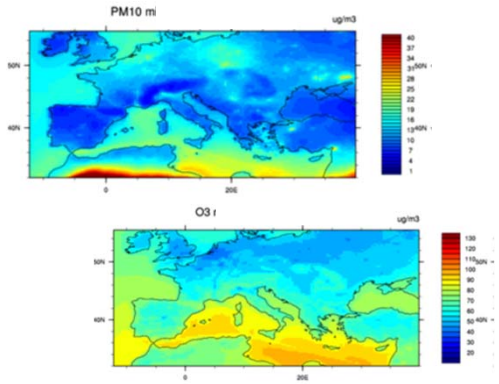
How do we tackle this issue in ENEA?

What will be the air pollutant concentrations in a future changing climate?

Future scenarios RCP2.6 and 8.5

Air quality + climate modelling



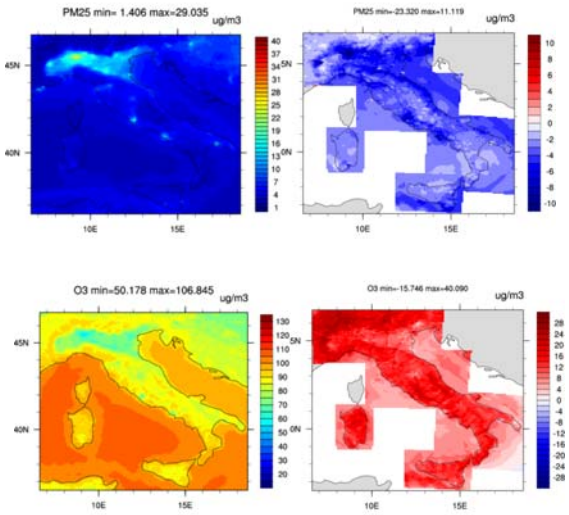


Mircea et al., 2014; 2016

https://doi.org/10.1016/j.atmosenv.2013.11.006

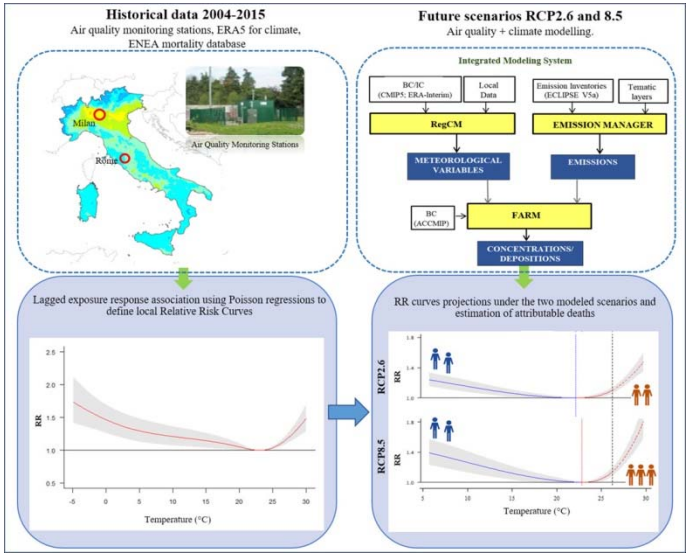
https://doi.org/10.4209/aaqr.2015.02.0058

One-way online nesting on the Italian domain (4 km)



How do we tackle this issue in ENEA?

Climate change and air pollution in future mortality risk for Rome and Milan municipalities

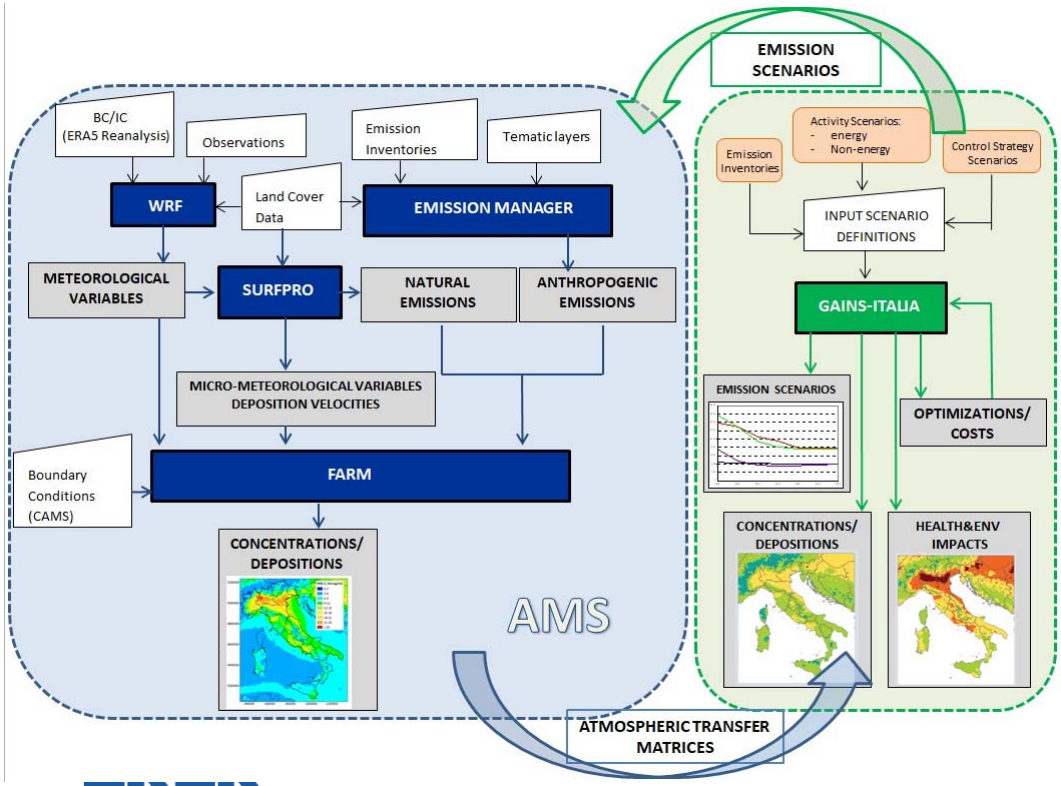


			Rome				Milan			
			Tot	Below T_{mm}	Above T_{mm}	T_{mm}	Tot	Below T_{mm}	Above T_{mm}	T_{mm}
All	Historical	Attrib. Ns	2379	1985 (83%)	394 (17%)	22°C	2033	1959 (96%)	74 (4%)	23.1 °C
		Attr. Fraction	*9.5* (5.97–12.52)	*8.0* (4.54–10.96)	*1.6* (0.83–2.31)		*15.7* (8.59–21.91)	*15.1* (8.04–21.35)	*0.6* (0.13–0.97)	
	RCP2.6	Attrib. Ns	2249	1833 (82%)	416 (18%)		1983	1861 (94%)	122 (6%)	
		Attr. Fraction	*9.0* (5.67–11.92)	*7.3* (3.96–10.26)	*1.7* (1.08–2.27)		*15.3* (8.28–21.48)	*14.4* (7.36–20.45)	*0.9* (0.52–1.35)	
	RCP8.5	Attrib. Ns	2326	1735 (75%)	591 (25%)		1977	1787 90%	189 (10%)	
		Attr. Fraction	*9.3* (6.08–12.12)	*7.0* (3.73–9.69)	*2.4* (1.67–3.11)		*15.2* (8.26–21.29)	*13.8* (6.96–19.76)	*1.5* (0.88–2.01)	
85+	Historical	Attrib. Ns	1454	1234 (85%)	220 (15%)	22.7 °C	1074	1046 (97%)	28 (3%)	23.3 °C
		Attr. Fraction	*15.4* (9.60–20.14)	*13.1* (7.34–17.90)	*2.3* (1.39–3.24)		*20.2* (9.0–29.30)	*19.7* (8.63–28.82)	*0.5* (–0.15–1.11)	
	RCP2.6	Attrib. Ns	1361	1141 (84%)	220 (16%)		1063	1008 (95%)	55 (5%)	
		Attr. Fraction	*14.4* (8.90–18.92)	*12.1* (6.58–16.81)	*2.3* (1.58–2.97)		*20.0* (8.98–29.04)	*18.9* (7.97–27.96)	*1.0* (0.39–1.62)	
	RCP8.5	Attrib. Ns	1398	1086 (78%)	312 (22%)		1057	971 (92%)	86 (8%)	
		Attr. Fraction	*14.8* (9.54–19.19)	*11.5* (6.20–16.03)	*3.3* (2.41 –4.19)		*19.9* (9.048–28.68)	*18.2* (7.47–27.04)	*1.6* (0.77–2.39)	

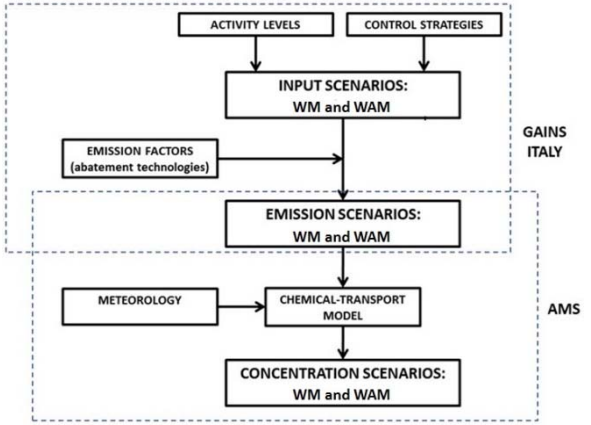
Michetti et al., 2022.
https://doi.org/10.1016/j.scitotenv.2022.154680
https://doi.org/10.1016/j.mex.2022.101717

How do we tackle this issue in ENEA?

INTEGRATED ASSESSMENT MODELING



Integrated Approach:
To assess the potential effects of new policies and measures aiming at reducing air pollution and climate change and their relative impacts

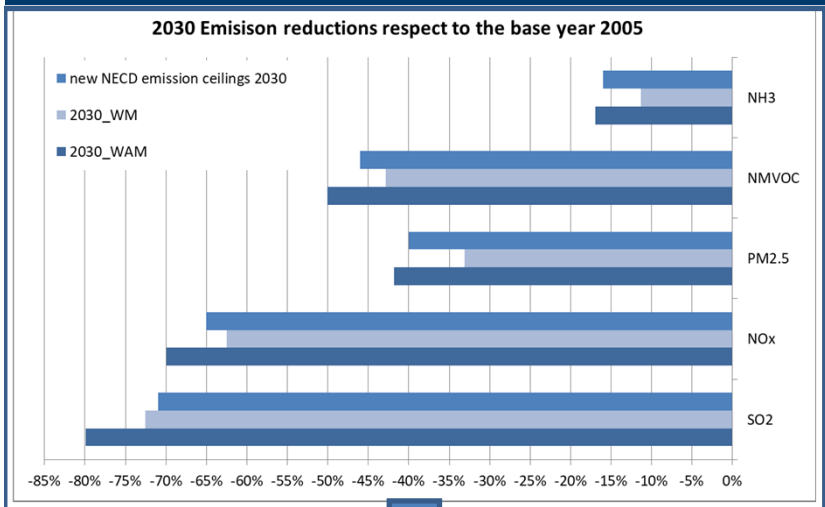


WM = With Measures; WAM = With Additional Measures

D'Elia et al., 2018

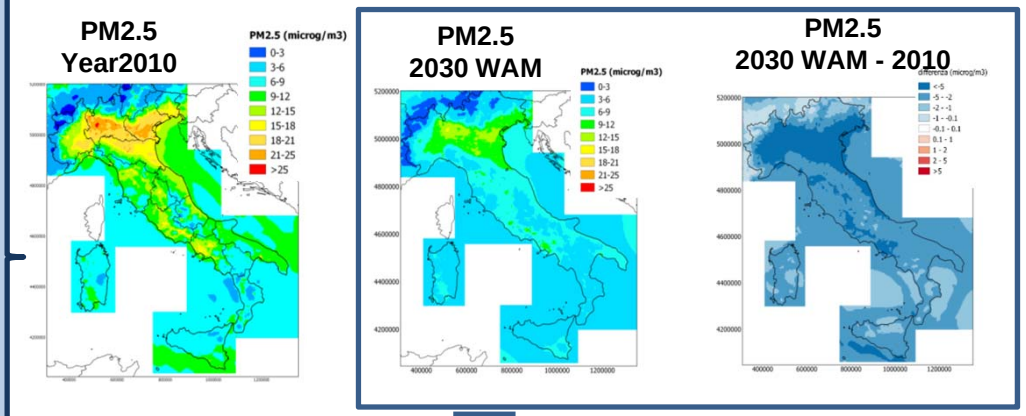
https://doi.org/10.1016/j.apr.2018.03.002

The first Italian National Air Pollution Control Programme



2030 Ceilings: non compliance for WM (With Measure) scenario (all pollutants but SO_2)
→ Additional measures needed (WAM)

WAM Compliance with NEC target… but what happens to air quality?

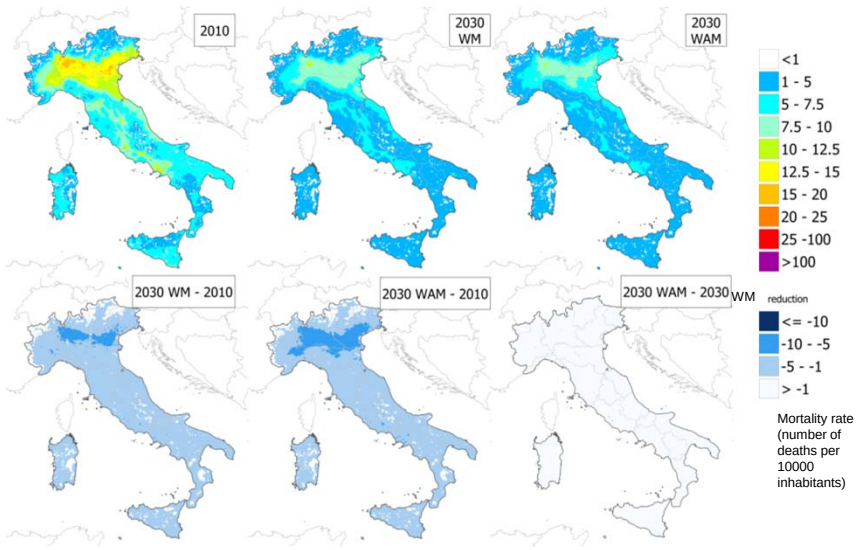


EU limit values attained but far from the WHO limits

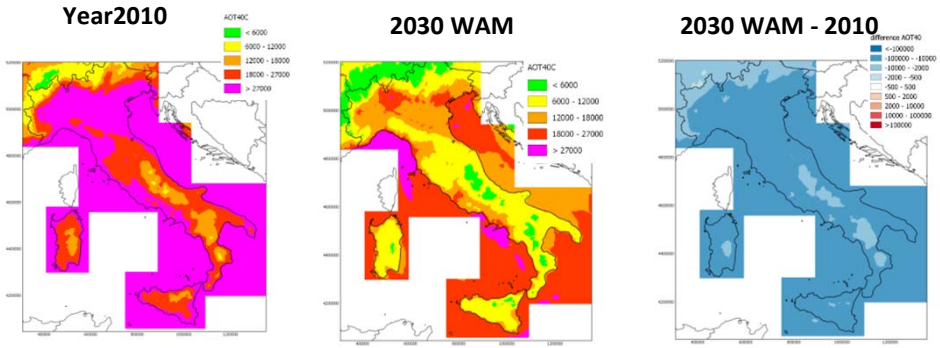
And what about health and environment impacts?

Health & Environmental Impacts

PM2.5 Mortality rate - WM and WAM



Ozone AOT40 vegetation - WAM



May to July
Targe value: 18 000 µg/m³
Directive 2008/50/EC

WM impacts substantially on the number of expected deaths

WAM brings an economical benefit equal to 2.05 % of Italian 2010 GDP, mainly in the Po Valley hot-spot, but not negligible (>1%) in several regions

WAM brings few minor benefits, and more efforts are needed

Piersanti et al., 2021 https://doi.org/10.3390/atmos12020196

The new Atmospheric Transfer Matrices: PM

Second Order Terms: PM_{10}, $PM_{2.5}$

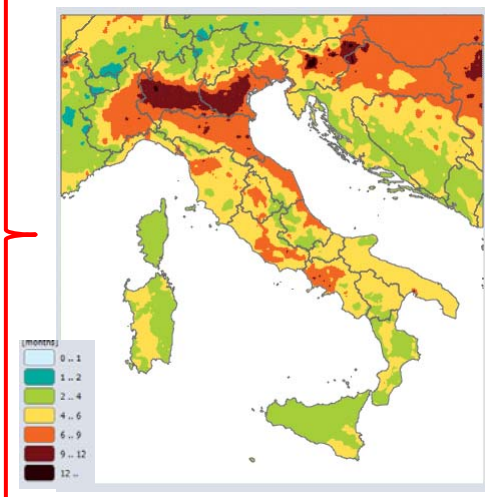
$$c = c_{ref} + \alpha \cdot \Delta PM_{10} + \beta \cdot \Delta NO_X + 0.5\,\gamma \cdot (\Delta NO_X)^2 + \delta \cdot \Delta NH_3 + 0.5\,\varepsilon \cdot (\Delta NH_3)^2 + \zeta \cdot \Delta SO_2 + \eta \cdot \Delta NMVOC$$

Meteo 2015

Meteo 2004

Meteo 2005

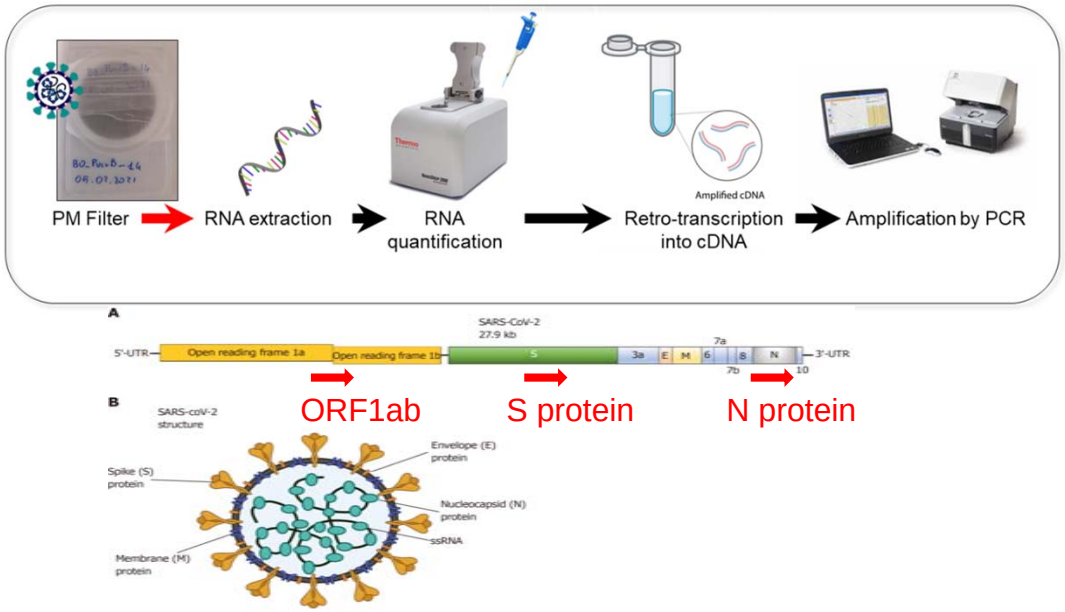
Life Expectancy reduction due to PM2.5 concentrations



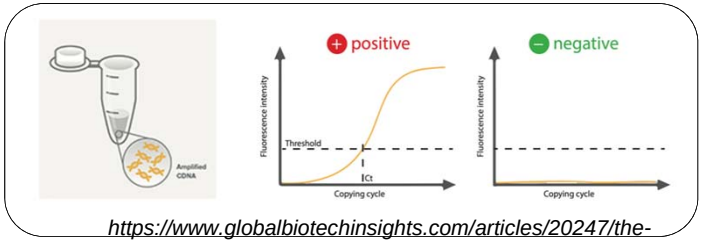
YEAR 2030 – avg ATM

Physical-chemical-biological interactions between fine particles and viruses

Viral genome characterization on quartz filter



Modified from: Galanopoulos M et al., 2020. World J Gastroenterol 2020; 26(41): 6335-6345



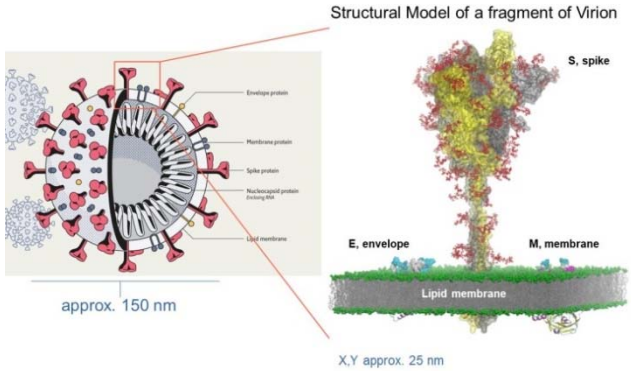
https://www.globalbiotechinsights.com/articles/20247/the-worldwide-test-for-covid-19

Date	Samples	ORF1ab	S Protein	N Protein		
19/01/2021	BO-PULVB-1			✓	✓	Viral genome fragment detected
21/01/2021	BO-PULVB-2					
22/01/2021	BO-PULVB-3					
23/01/2021	BO-PULVB-4	✓	✓			
24/01/2021	BO-PULVB-5	✓		✓		
25/01/2021	BO-PULVB-6					
26/01/2021	BO-PULVB-7	✓				
27/01/2021	BO-PULVB-8	✓				
28/01/2021	BO-PULVB-9		✓			
29/01/2021	BO-PULVB-10	✓		✓		

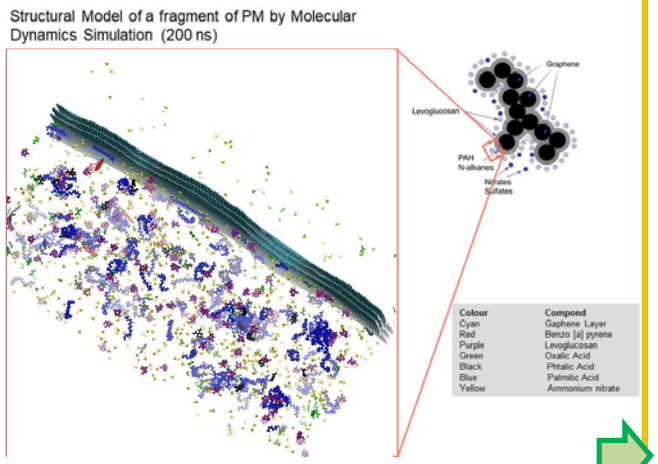
National project Pulvirus
https://www.pulvirus.it/

Physical-chemical-biological interactions between fine particles and viruses: In Silico Molecular Modeling

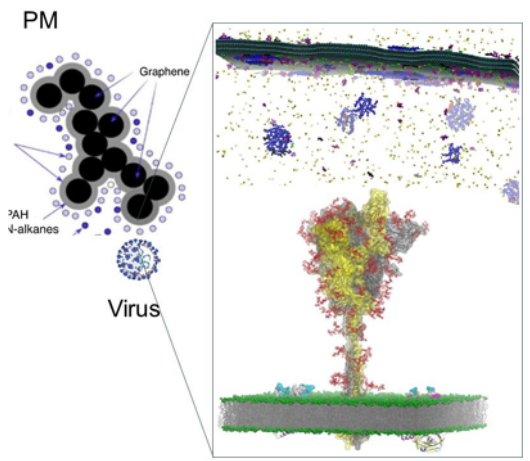
VIRUS Molecular modelling



PM Molecular modelling



Molecular Modelling of VIRUS-PM Interface



National project Pulvirus
https://www.pulvirus.it/

All the simulations are run on the HPC ENEA-CRESCO

What we have learnt

- These activities tested the robustness of model responses for policy support, both on short term severe emission reductions and on long term air quality plans.
- The complexity of the interactions and feedback of human activities with/to the environment require modelling tools that can apply **HOLISTIC APPROACHES**.
- The pandemic shows the need to integrate different physical-chemical-biological interactions using different tools (developing the in silico molecular modeling).
- Urgent need of **integrated models** to evaluate the impacts of expected **integrated policies** (on energy, air pollution and climate) to tackle possible negative effects on air quality and climate change.

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Thank you for your attention