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Integrated Climate forcing and Air pollution Reduction in Urban Systems

AIR POLLUTION HEALTH IMPACT ASSESSMENT AND COST-BEENFIT ANALYSIS OF WIN-WIN POLICY SOLUTIONS AT THE URBAN SCALE IN THE CITY OF MILAN

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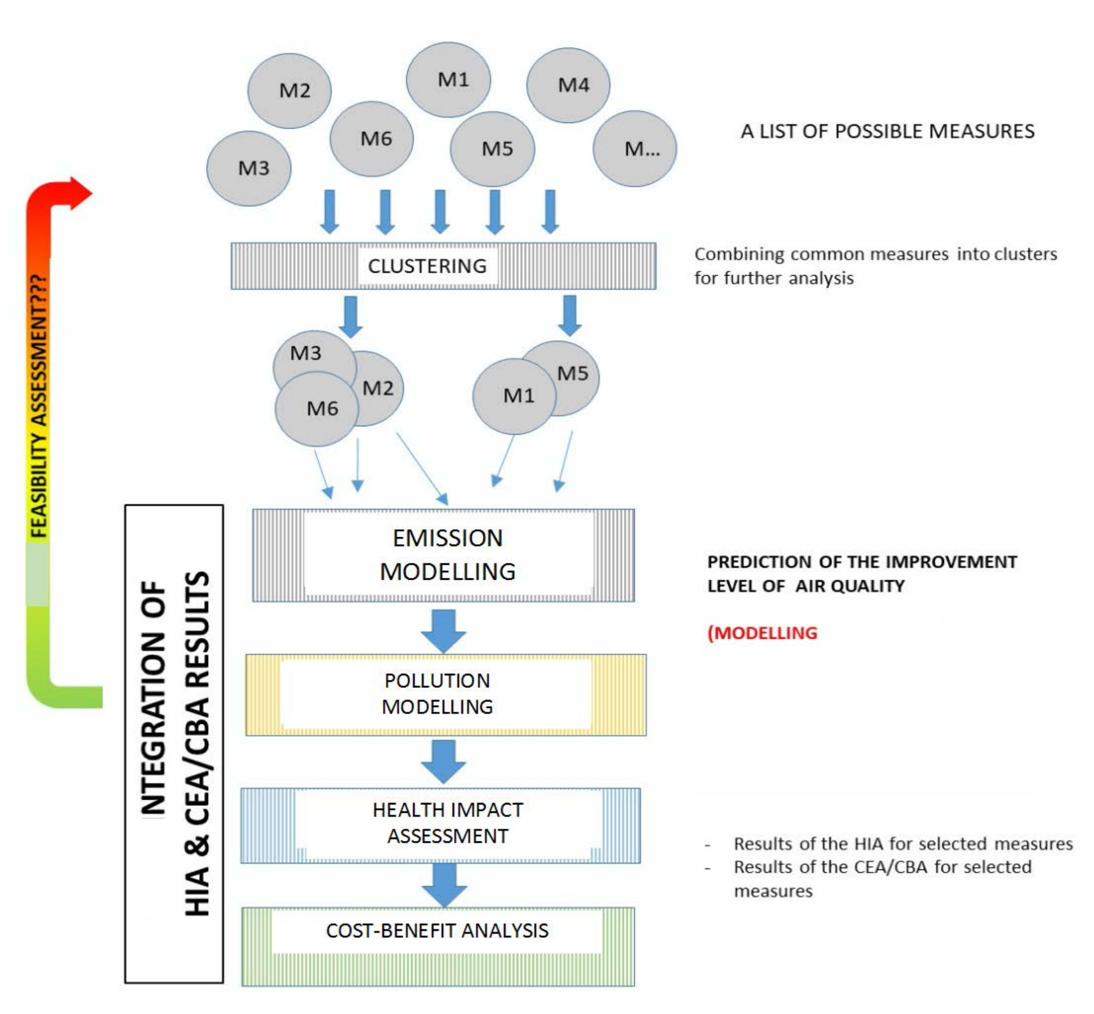
This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

AIMS

Schematic representation of the concept and related work

potential implementation of selected measures and policy options towards integrated win-win solutions (2020 – 2030)

(1) emissions of air pollutants;
(2) emissions of greenhouse gases;
(3) ambient concentration of (1) and (2);
(4) Exposure of people to air pollutants;
(5) associated impacts on human health (HIA);
(6) Cost – Benefit Analysis (CBA)



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Milan City – Emission Scenarios

H2020-SC5-2015 - GA: 690105

- Baseline (2015)
- BAU 2020 and 2030

EMISSION = ACTIVITY x EMISSION FACTOR

spatially distributed within the city area

(1 km x 1 km grid)

- BOTTOM-UP and TOP-DOWN approaches

List of pollutants and GHGs for which emission factors are available

Greenhouse gases	**"Classical" air pollutants**	**Heavy metals, PAH, dioxins**
1. CH_4	1. PM_{10}	1. Cadmium
2. CO_2	2. $PM_{2.5}$	2. Arsenic
3. N_2O	3. Black carbon	3. Mercury
	4. Organic carbon	4. Lead
	5. NO_x	5. Benzo(a)pyrene as marker substance for total PAHs (polycyclic aromatic hydrocarbons)
	6. SO_2	
	7. CO	
	8. NH_3	6. PCDD/PCDF as indicator for dioxins and furans
	9. NMVOC	

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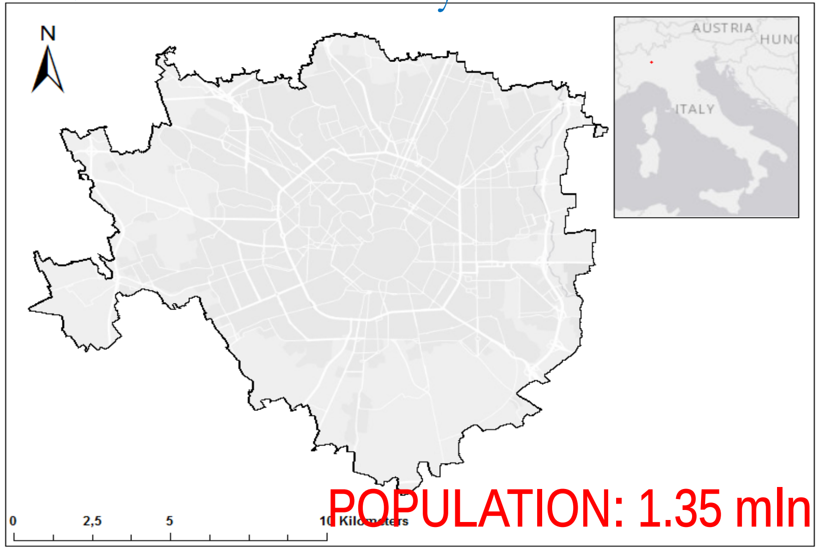
Milan City – Emission Scenarios 2015 and 2020-2030

the borders of the city of Milan under study



POPULATION: 1.35 mln

Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

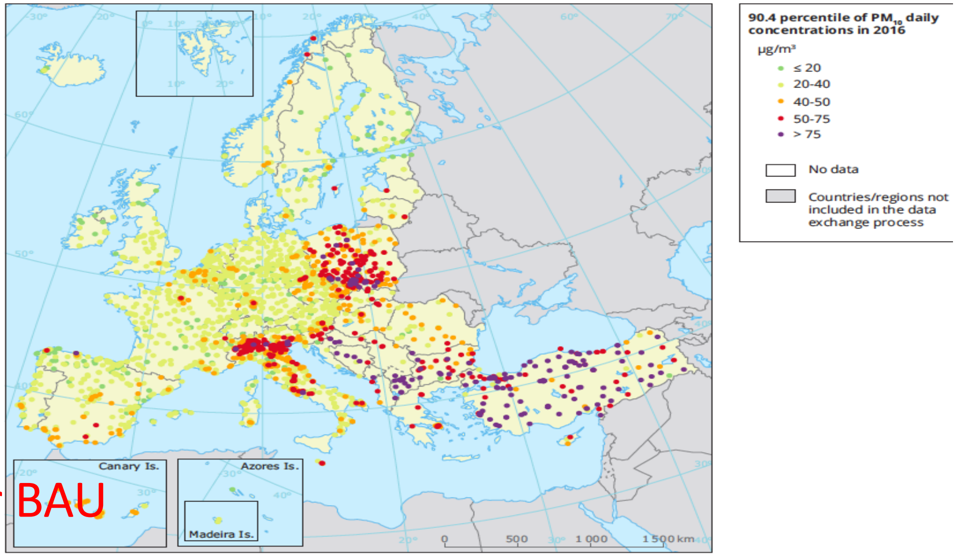
Bottom-up data:

INEMAR emission inventory (SNAP 97 nomenclature → translated into NFR09 = top-down)

SPATIAL DISAGGREGATION 1 km * 1

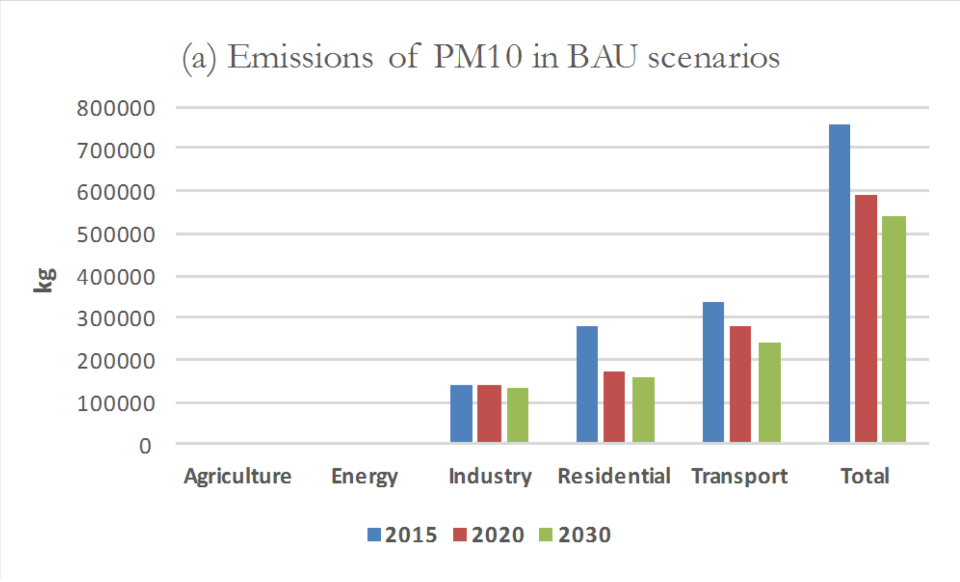
$$E_i = A * EF_i$$

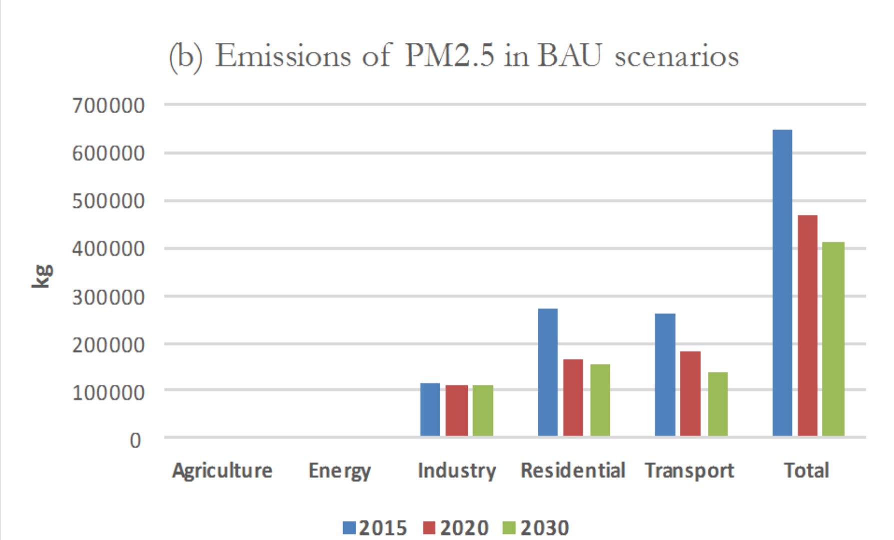
+ Backward calculation for 2020 -2030 for BAU

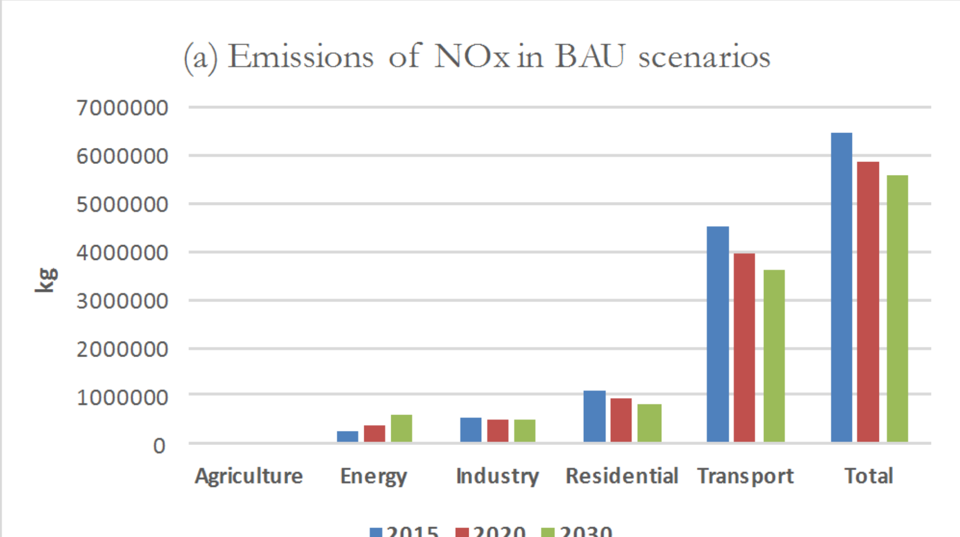


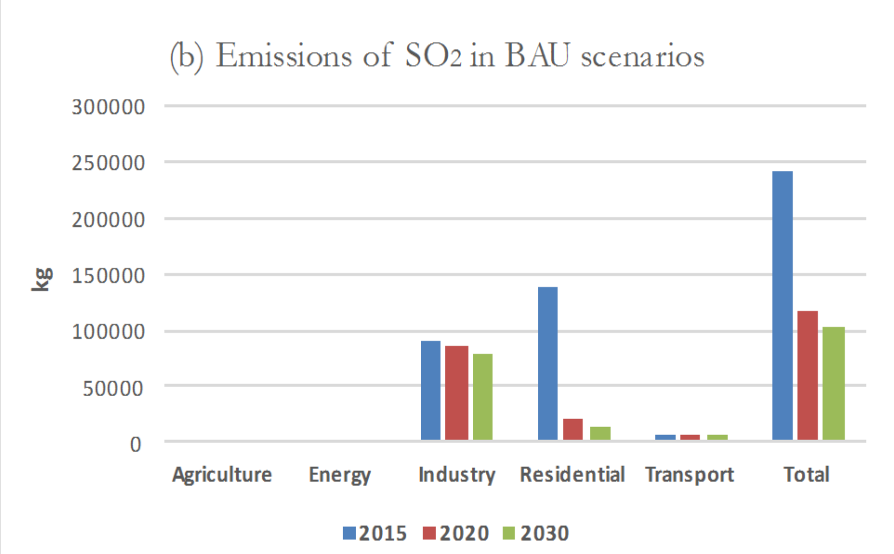
Notes: Observed concentrations of PM_{10} in 2016. The possibility of subtracting contributions to the measured concentrations from natural sources and winter road sanding/salting has not been considered. The map shows the 90.4 percentile of the PM_{10} daily mean concentrations, representing the 36th highest value in a complete series. It is related to the PM_{10} daily limit value, allowing 35 exceedances of the 50 μg/m³ threshold over 1 year. Dots in the last two colour categories indicate stations with concentrations above this daily limit value. Only stations with more than 75 % of valid data have been included in the map. The French overseas territories' stations are not shown in the map but can be found at https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics.

Milan City – Emission Scenarios BAU 2020 - 2030









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The impacts of the five selected policy options were carried out under the assumption of RCP4.5 scenario for climate change

	Resolution (sectors)	Resolution (geographical)
Emissions of greenhouse gases		
CO_2	Energy/industry, land	Global and for 5 regions
CH_4	12 sectors	0.5°×0.5° grid
N_2O, HFCS, PFCS, CFCS, SF_6	Sum	Global and for 5 regions
Emissions aerosols and chemically active gases		
SO_2, black carbon (BC), organic carbon (OC), CO, NOx, VOCs, NH_3	12 sectors	0.5°×0.5° grid
Speciation of VOC emissions		0.5°×0.5° grid
Concentration of greenhouse gases		
(CO_2, CH_4, N_2O, HFCS, PFCS, CFCS, SF_6)	-	Global
Concentrations of aerosols and chemically active gases		
(O_3, aerosols, n deposition, s deposition)	-	0.5°×0.5° grid
Land-use/land-cover data	Cropland, pasture, primary vegetation, secondary vegetation, forests	0.5°×0.5° grid with subgrid fractions, (annual maps and transition matrices including wood harvesting)

RCP4.5 Stabilization of radiative forcing without overshoot pathway to 4.5 W/m^2 (~650 ppm CO_2 eq) at stabilization after 2100

AIR QUALITY MODELLING AND CLUSTERING

Pollutant Concentration Trends: pollutant representative air concentration (CR)

Emission Trends Influence:
representative days for the clusters with high [air pollutants] have been simulated with 3 EI: 2015, 2020 and 2030

Green House Gases (GHGs):
6-hour frequency 1951 to 2100
CO_2 and CH_4 anthropogenic emissions (ICARUS db). Results 12*12 km

$$CR(\Delta\tau) = \sum_{n=1}^{N} f_n(\Delta\tau) \cdot CRD_n(\Delta\tau)$$

N = total number of Clusters

$f_n(\Delta\tau)$ = frequency of occurrence of cluster n during the time period $\Delta\tau$

$CRD_n(\Delta\tau)$ = concentration under study corresponding to the representative day of the cluster n during the time period $\Delta\tau$

FINAL RESULTS: high space and time resolution ground concentrations reflecting climatic trends until 2050, of air pollutants (PM10, PM2.5, NO_2, O_3) and GHGs (CO_2, CH_4) in Milan and to assess the effect emissions changes

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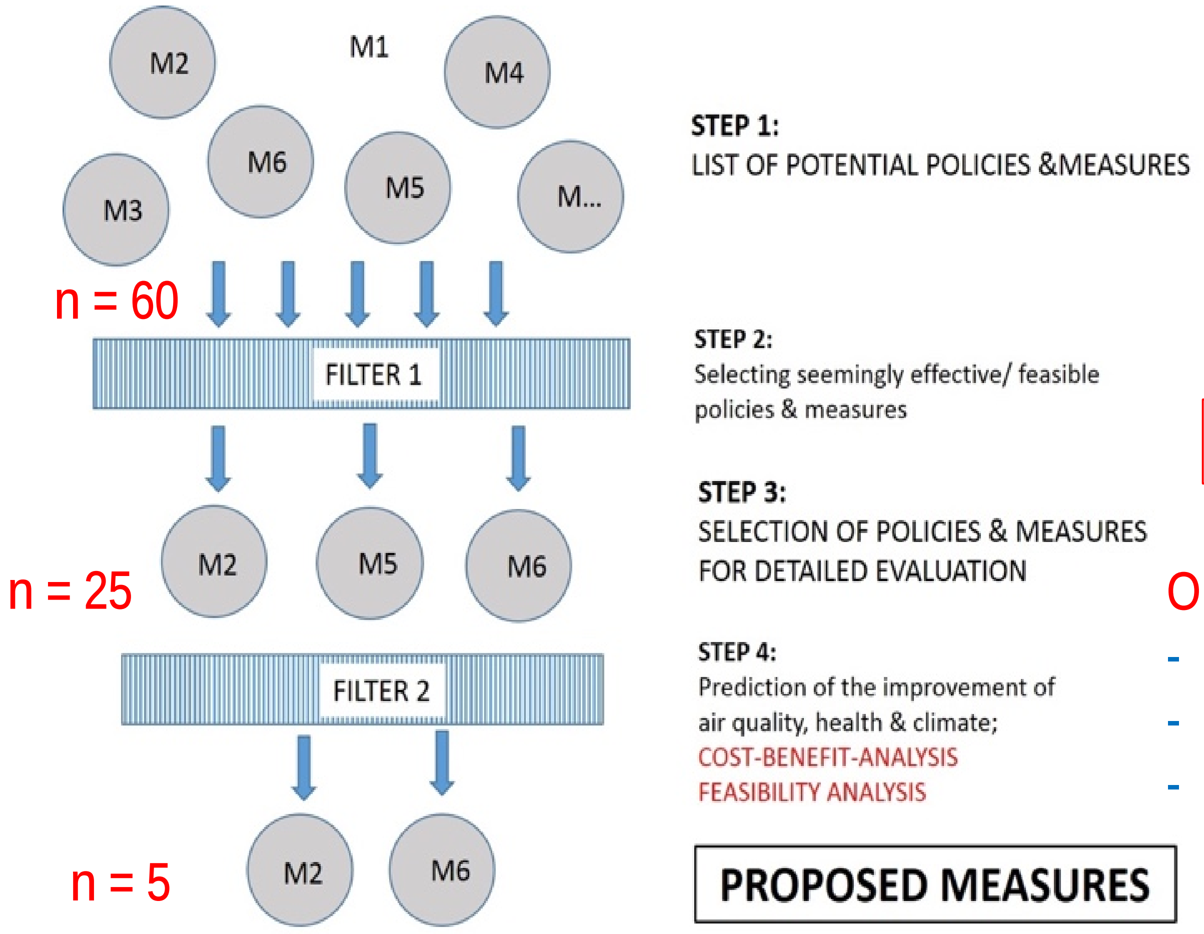
Policies evaluation



INPUTS

- selected city measures
- activity-emission-factor DB or EI (spatially distributed)
- emission reduction potential

STAKEHOLDERS ENGAGEMENT

OUTPUTS

- New 5 EI scenarios (2020-2030)
- New Input in AQ modelling
- Input for Health Impact Assessment (HIA) and Cost Benefit Analysis (CBA)

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Policies and measures for the Milan case study

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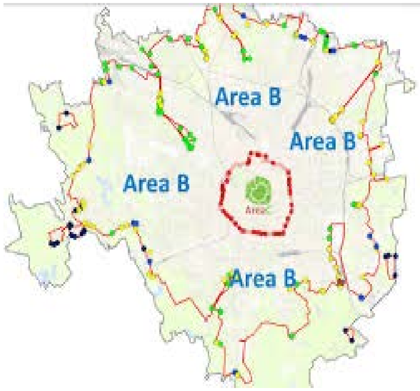
TRANSPORTS

(1) Low Emission Zone ("Area B")
Limitation to polluting vehicles
Steps year-by-year 2019-2030
Complete banning of diesel (2030)

(2) Conversion of public buses to electric ones
From 2020 renewal: exclusively electric vehicles
2030: whole bus fleet converted (1200 vehichles)



BUILDINGS

(3) Improvement of energy efficiency in residential flats
package of regulations (existing and new buildings)
Financial incentives: renovation, energy savings, etc.

ENERGY SUPPLY

(4) Photovoltaic / solar power + district heating
Incentive measures of new building regulation
city's district heating network, 730,000 people

LAND USE

(5) Planting of 25000 new trees per year
3 million trees by 2030 in metropolitan city
green canopy area from 7% to 20%

Selection Criteria: Effectiveness, Efficiency, Acceptability

Emission reduction potential – results

Emission variation (%) in policies scenarios 2020 (a) and 2030 (b) compared to BAU

(a) Year 2020	NH_3	NMVOC	NO_x	PM_{10}	$PM_{2.5}$	SO_2
BAU						
AreaB	-4,21%	-0,68%	-10,80%	-6,81%	-6,24%	-1,19%
ElectricBus	-0,05%	-0,02%	-1,01%	-0,20%	-0,14%	-0,03%
Buildings	0,00%	-0,06%	-0,69%	-0,04%	-0,05%	-0,49%
Energy	0,00%	-0,06%	-1,29%	-0,18%	-0,23%	-4,60%
Trees	0,00%	0,00%	-0,01%	-0,16%	-0,03%	-0,21%

(b) 2030	NH_3	NMVOC	NO_x	PM_{10}	$PM_{2.5}$	SO_2
BAU						
AreaB	-7,25%	-4,71%	-54,67%	-19,87%	-16,60%	-4,89%
ElectricBus	-0,43%	-0,05%	-7,65%	-1,61%	-0,68%	-0,28%
Buildings	0,00%	-0,22%	-2,69%	-0,16%	-0,21%	-2,10%
Energy	0,00%	-0,15%	-3,06%	-0,27%	-0,36%	-1,59%
Trees	0,00%	0,00%	-0,09%	-2,06%	-0,45%	-2,75%

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Emission reduction potential – results

Total greenhouse gas emission reductions for the city scenarios

	2020			2030		
Measure name	CH_4 [kg]	CO_2 [kg]	N_2O [kg]	CH_4 [kg]	CO_2 [kg]	N_2O [kg]
Buildings	-2876	-63281097	-1151	-10759	-236702720	-4303
Electricbus	-171	-3057103	-192	-426	-9759901	-1385
Energy	-4083	-89419270	-1250	-8188	-198908550	-2539
Trees	0	-800000	0	0	-8800000	0
Area B	-5085	-209950556	-8134	-16377	-653301684	-28283

climatic trends (for all measure scenario) from 2021 to 2050:

- O_3 decrease in the years 2021-2035 and then an increase.
- PM_{10} and $PM_{2.5}$ increase for years 2021-2035

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“scientific evaluation of potential adverse health effects resulting from human exposure to a particular hazard (i.e. air pollution);
[…]
a comprehensive approach to the evaluation of the current state-of-the-environment and of future conditions following specific abatement scenarios”
(WHO)

(i) amount of air pollution present, i.e. pollutant concentrations (CRFs);
(ii) the amount of contact (exposure) of the targeted population to pollutants;
(iii) how harmful the concentration is for human health, i.e. the resulting health risks to the exposed population.

+ Spatial /Geographic Information Science!

population attributable risk fraction (AF):

$$AF = \frac{\sum_i P_i \cdot RR_i - 1}{\sum_i P_i \cdot RR_i}$$

P_i is the proportion of the population at exposure category *i*
RR_i is the relative risk at exposure category *i* compared to the reference level

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HEALTH IMPACT ASSESSMENT RESULTS

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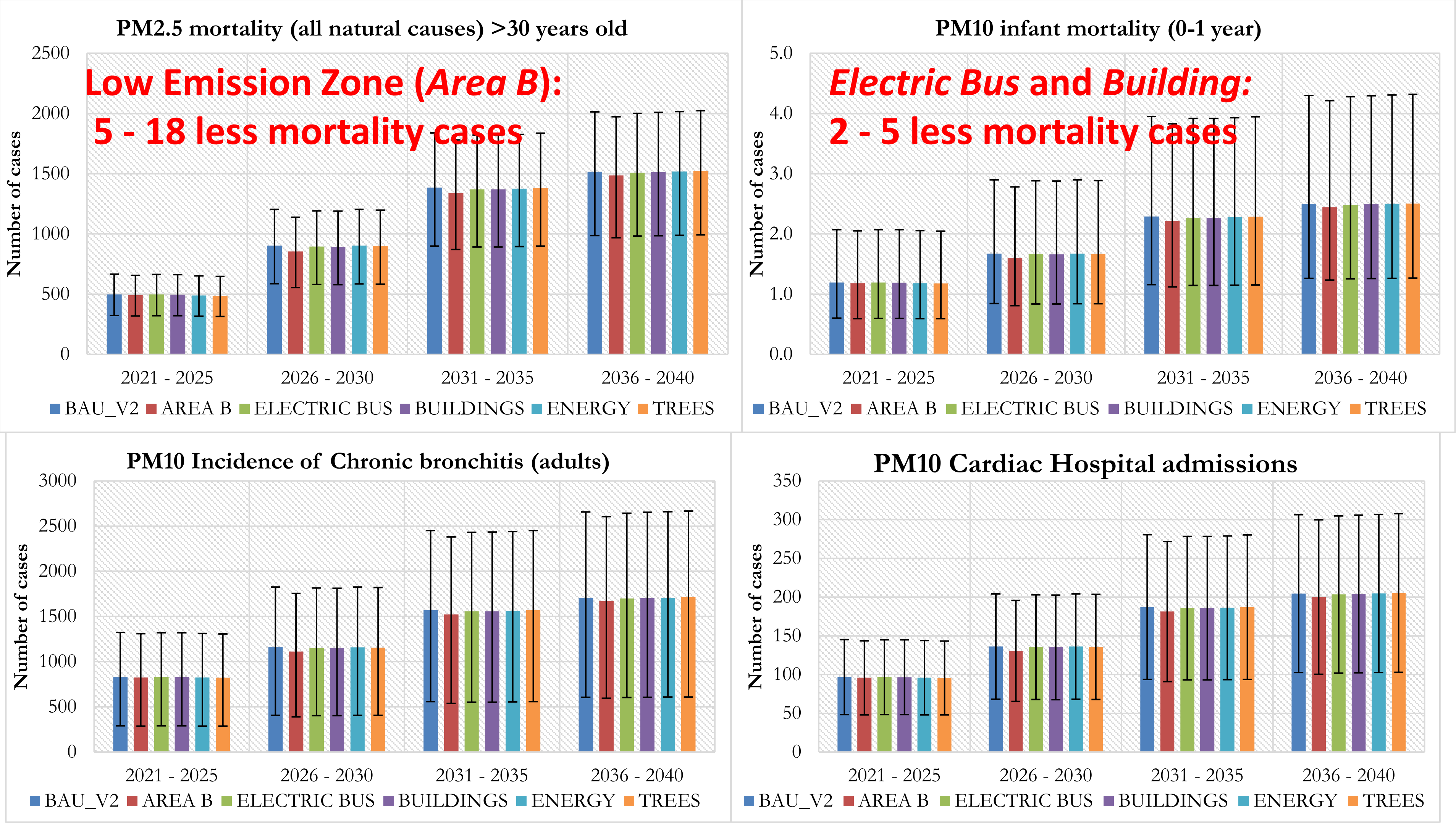
20th MESAEP Symposium - ICARUS session 26-27/10/2020

Whole Simulated Domain Area (50 x 50 km)



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HEALTH IMPACT ASSESSMENT RESULTS

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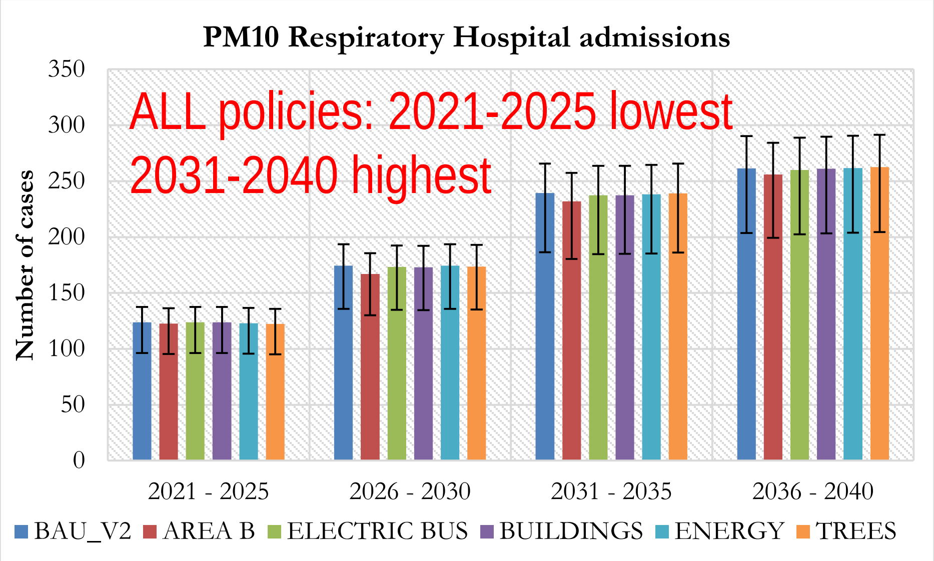
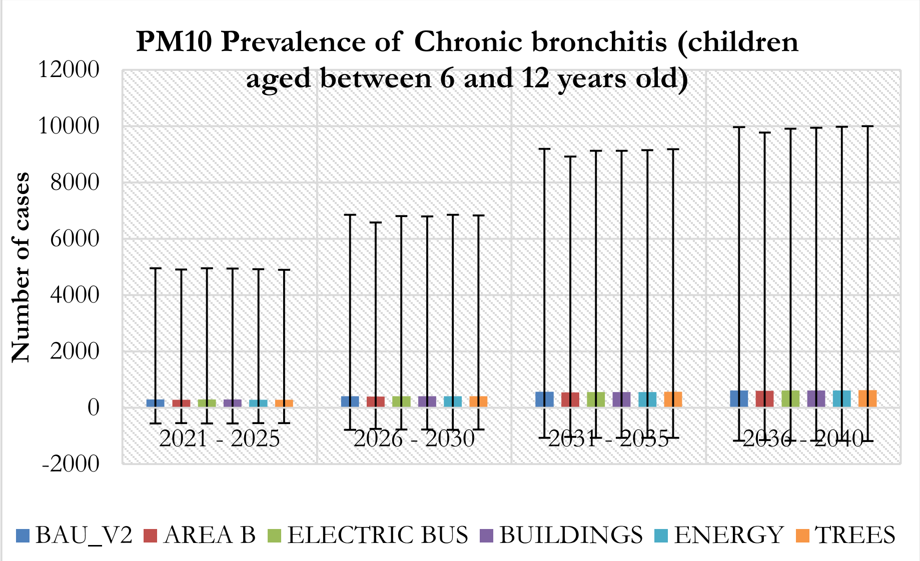
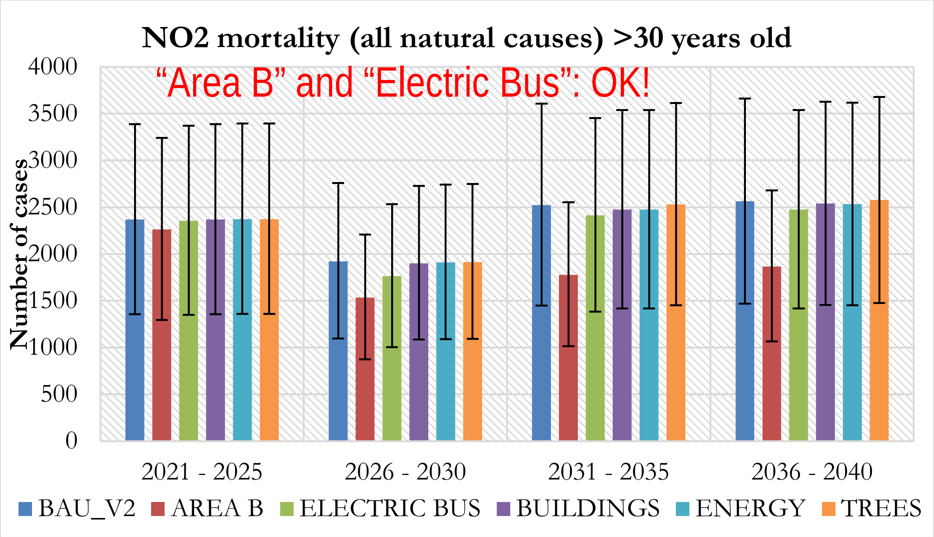
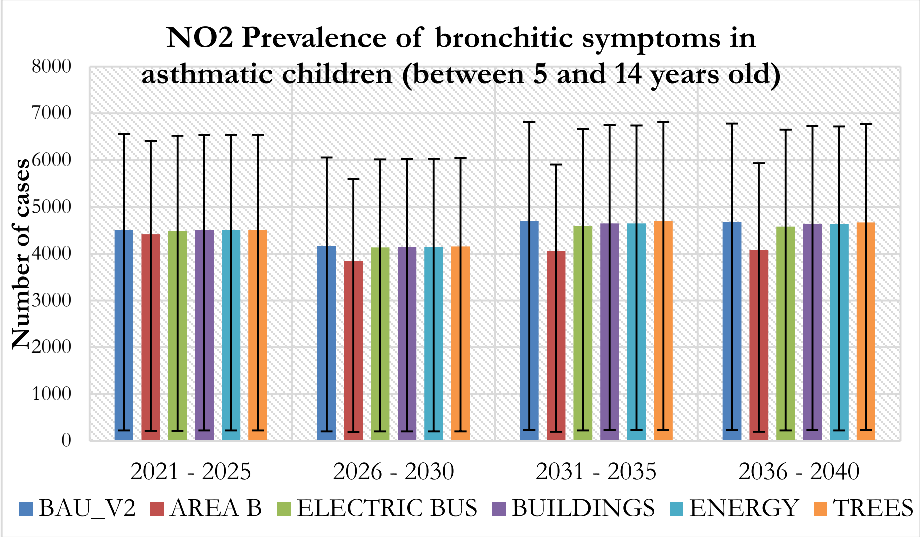
Whole Simulated Domain Area (50 x 50 km)









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COST-BENEFIT ANALYSIS

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Results of the Cost-benefit analysis and Cost-effectiveness

MEASURES/ POLICY SCENARIOS	M1 Milan area B	M2 Milan e-bus	M3 (energy)*	M4 (buildings)*	M5 Milan trees
	Low Emission Zone	Replacement of entire bus fleet with electric buses	Energy efficiency improvements	Solar power in buildings	Green area and new trees
Net Present Costs (€)	14,272,436	77,187,492	unknown	unknown	49,496,900
Net present health benefits (€)	11,964,987,522	2,454,269,532	632,400,540	761,524,521	83,830,490
Net Present Other non-health benefits (€)	29,041,252				
Net Present Value Carbon savings (€)	158,871,091	2,402,922	55,898,495	56,134,451	1,641,954
Net present total benefits (€)	12,152,899,865	2,456,672,453	688,299,035	817,658,972	85,472,444
NPV (€)	12,138,627,429	2,379,484,961	688,299,035	817,658,972	35,975,544
B/C Ratio	851.49	31.83	* costs missing information		1.73
FICOSTEF	2.61	932.57			875.17
FUCOSTEF	- 2,189	- 28,719			- 607

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Result of policies assessment

	Impacts				
Policies	Emissions	Air pollution	Health	CBA	GHG
Transport «Area B» (LEZ)	++	+	+	++	++
Transport Electric Bus	+	O	+	++	+
Buildings	O	O	O	(+) / unknown costs	++
Energy	O	O	O	(+) / unknown costs	+
Land use (trees)	n/a	+	O	+	O

CONCLUSIONS

- SET-UP methodology to create EI scenarios → Evaluation of Policies → AQ modelling → HIA → CBA
- Strategies which allowed the city partners and main polluters to engage with this issues, and settle to the win-win solution for AIR QUALITY and CLIMATE CHANGE
- Building ongoing communication and lifelong partnerships with parties
- "PEOPLE FIRST": Transfer ownership of the policies to citizens
- Assisted and trained stakeholders in urban impact assessment as well as educate them about the health and environmental benefits
  (engagement strategy – decision making process)
- Series of recommendations to policy makers:
  minimise the pollution and their consequent health effects
- Raised citizen awareness regarding the impacts of their activities on air pollution and climate forcing and increase societal acceptance of emission reduction policies

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EUCENTRE FOR YOUR SAFETY.

https://www.eucentre.it

https://icarus2020.eu

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ADDITIONAL SLIDES

AIR QUALITY MODELLING AND CLUSTERING

Pollutant Concentration Trends: pollutant representative air concentration functions (CRFs)

WRF-Chem : Weather Research and Forecasting (WRF) model coupled with Chemistry

emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with the meteorology

$$CR(\Delta\tau) = \sum_{n=1}^{N} f_n(\Delta\tau) \cdot CRD_n(\Delta\tau)$$

N = total number of Cluster n

$f_n(\Delta\tau)$ = frequency of occurrence of cluster n during the time period $\Delta\tau$

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COST-BENEFIT ANALYSIS

- **Net Present Value (NPV)** of total discounted costs and benefits;
- **Benefit/Cost Ratio (B/C)**

cost-effectiveness analysis:

- Financial cost-effectiveness (FICOSTEF): financial cost per tC saved (CO_2equivalent)
- Full cost-effectiveness (FUCOSTEF): full cost (costs-benefit) per tC saved (CO_2equivalent)

General assumptions and Monetary Valuation of Impacts

Discounting: 3.5% discount rate (cost of capital) – all values in 2018 prices

Time horizon of the CBA: initial investment year – last HIA year available

Value of Carbon: Social Cost of Carbon (SCC) set at $31 (€$_{2018}$29.03)

Health Endpoint valuation: [Hunt, 2011] central figure, and a low and high estimate

Health benefits from walking and cycling: WHO Europe Health Economic Assessment Tool

Noise: traffic reductions; switching from conventional cars to electric vehicles [Litman, 2011]

Accidents: Benefit with shift from conventional car other transport modes [Litman, 2011]

Travel time losses: Costs with shift from conventional car other transport modes [Litman, 2011]

Biomass burning issue – Pizza: the Italian “taboo”

In 2015 (official EI), PM10 from «pizzerie»:

16% of the total emission in Milan

(residential plants: 5.6%; industry sector: 1.5%)

Benzo[a]Pyrene: 33,4% of the total BaP emission

FUTURE WORK

- A multi-objective optimization methodology will be devised encompassing high dimensional data fusion and refined tools for environmental and health impact assessment;

- Integration of complex systems dynamics that incorporate the interactions between activity sectors and the respective behavioural changes (Agent Based Modelling – ABM);

- Health impact assessment will incorporate internal dosimetry methodologies (PM sizes);

SENSOR CAMPAIGNS run in 2019 winter and summer in Milan (100 citizens)

Personal exposure to air pollutants – indoor & outdoor

- Results of the policy analyses will allow to determine the most sustainable GHG mitigation and AQ improvement strategies (guidance for decision-making): maximizing the net public health and wellbeing benefits while taking into consideration the costs associated with air pollution and climate change in the EU;

- Decision Support System (DSS): interactive platform for selection, application and evaluation of the available datasets and tools for urban impact assessment + web- and smartphone-based tool (lifestyle and carbon footprint)