

Air Quality and Low Carbon plans synergies in a high polluted area

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IAMlab-UNIBS

Integrated Assessment Modelling Lab

Context



PM2.5 annual mean concentration, $\mu\text{g}/\text{m}^3$

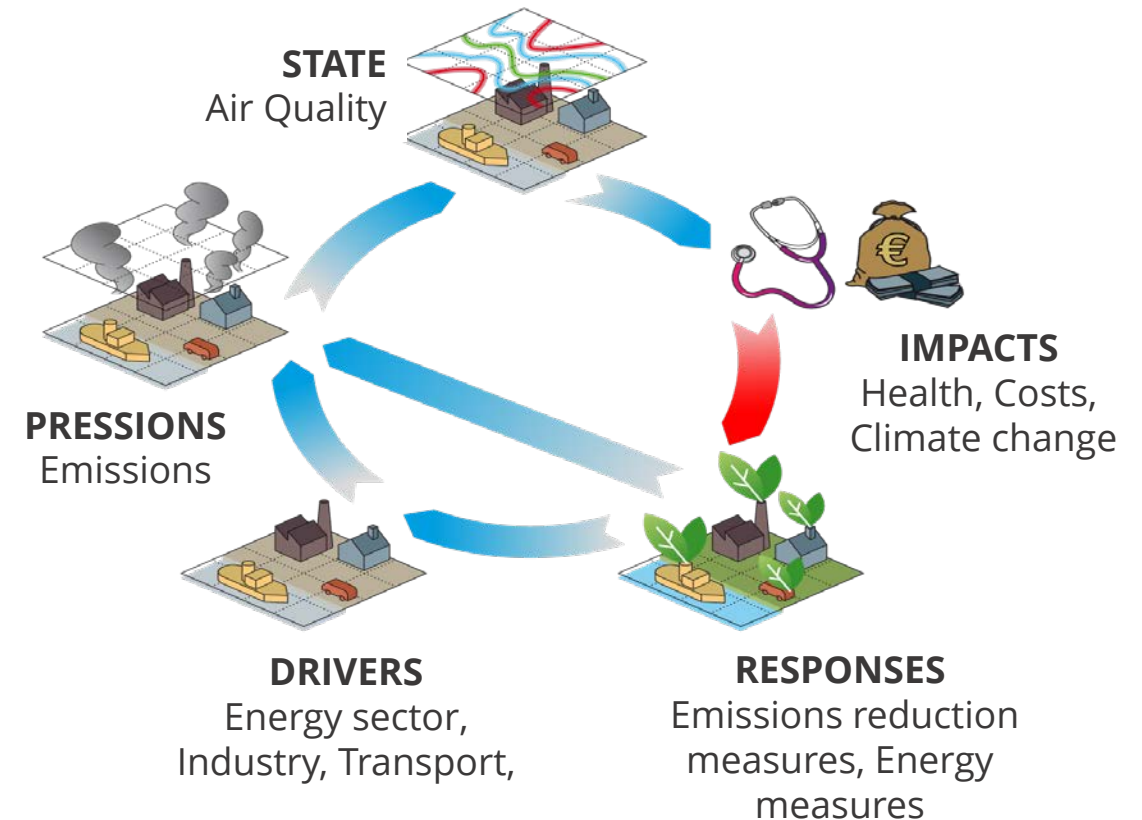
5 - 10	fair	
10 - 15	moderate	
15 - 25	poor	
> 25	very poor	
no data	-	



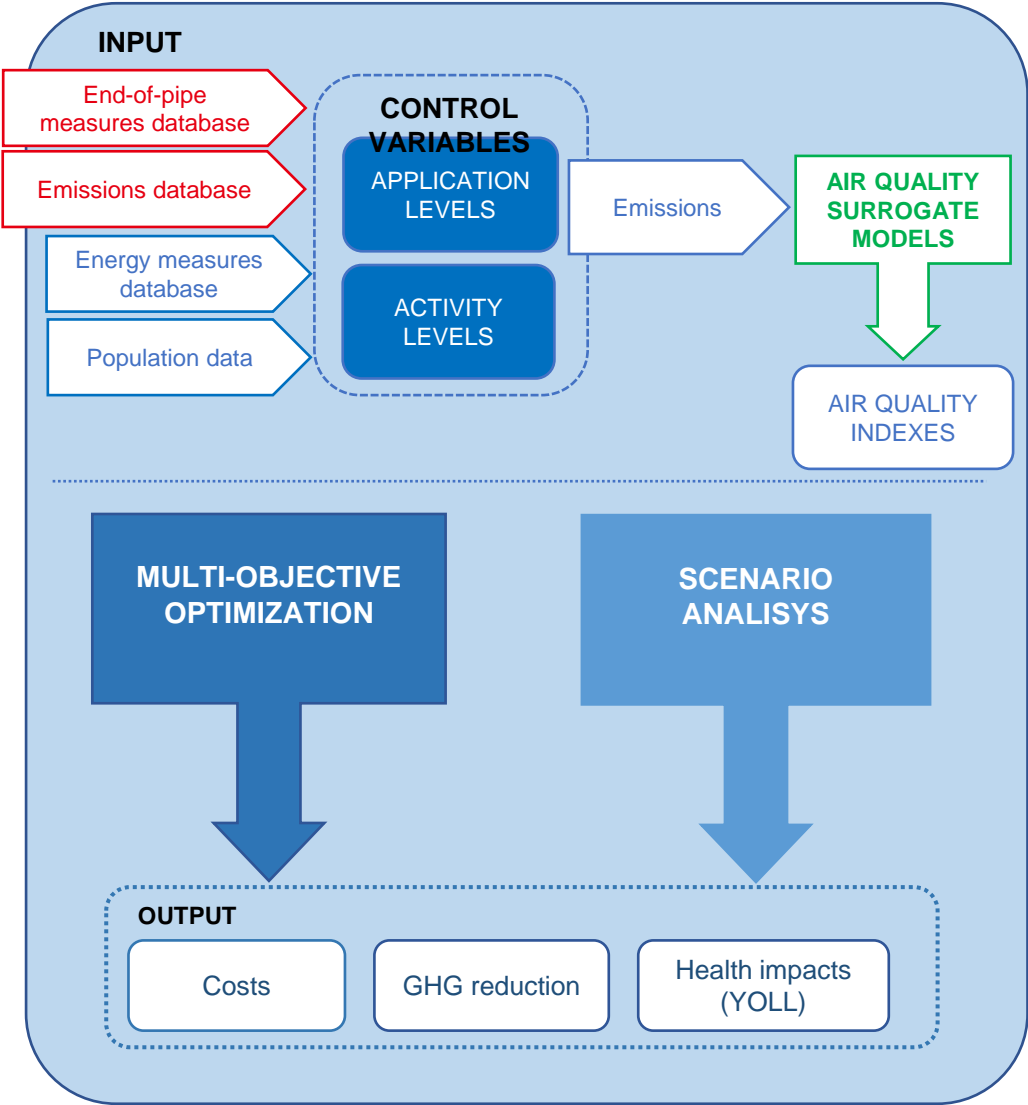
Outline

Integrated assessment of low-carbon and air quality efficient plans for the Lombardy region:

- 2020 base-case scenario
- 2030 regional Energy plan
- 2030 Air Quality and Energy plan

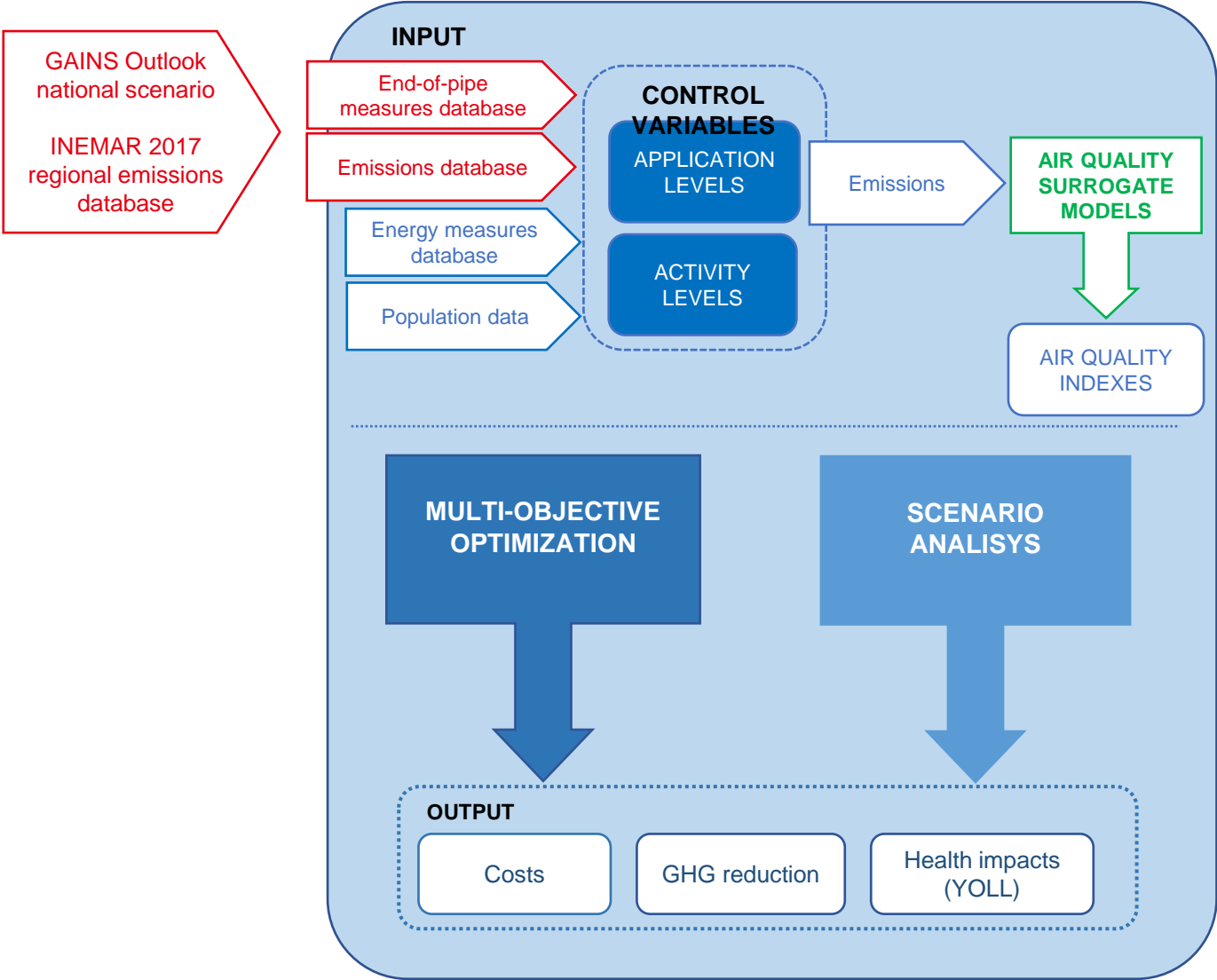


MAQ Model

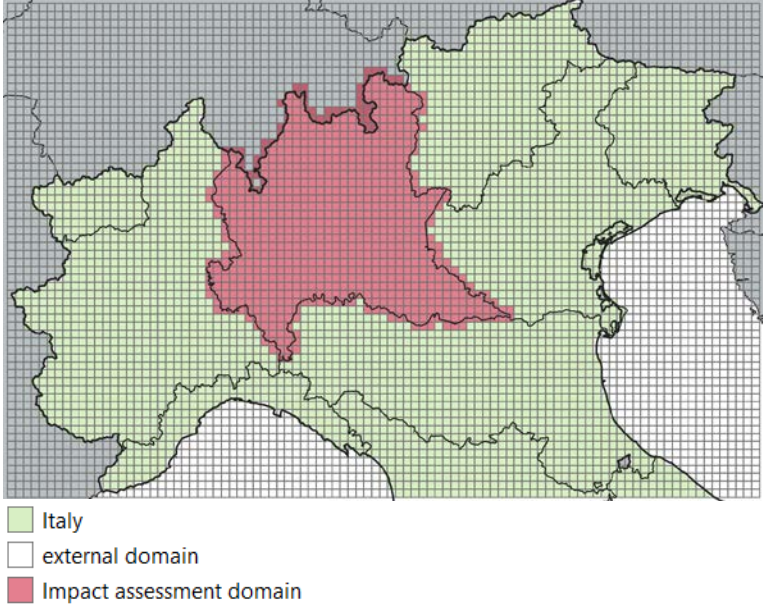


E. Turrini, C. Carnevale, G. Finzi, M. Volta, *A non-linear optimization programming model for air quality planning including co-benefits for GHG emissions*, Science of The Total Environment, 2018
<https://doi.org/10.1016/j.scitotenv.2017.10.129>.

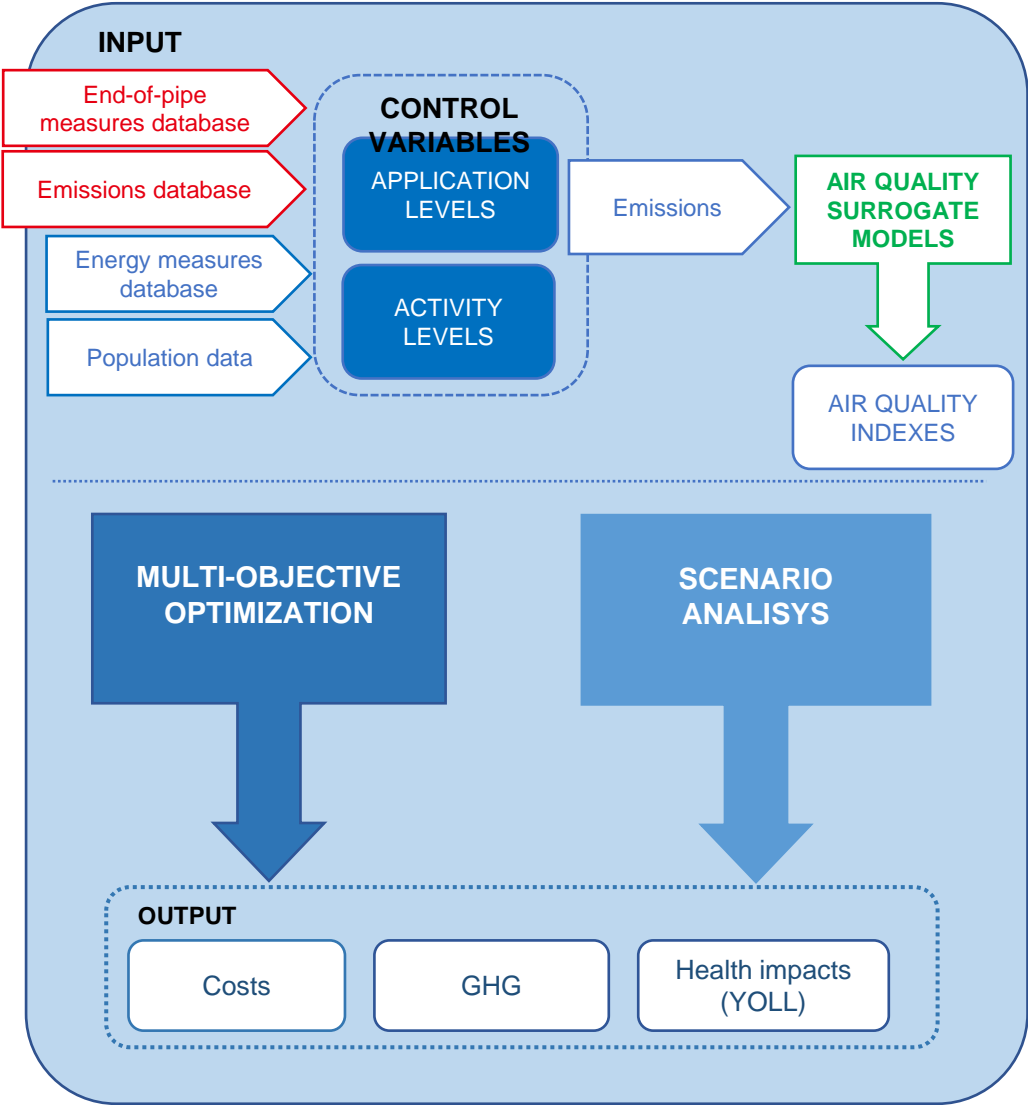
MAQ Model



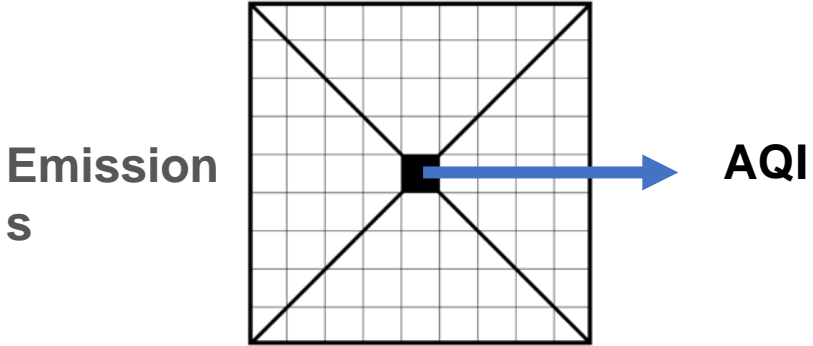
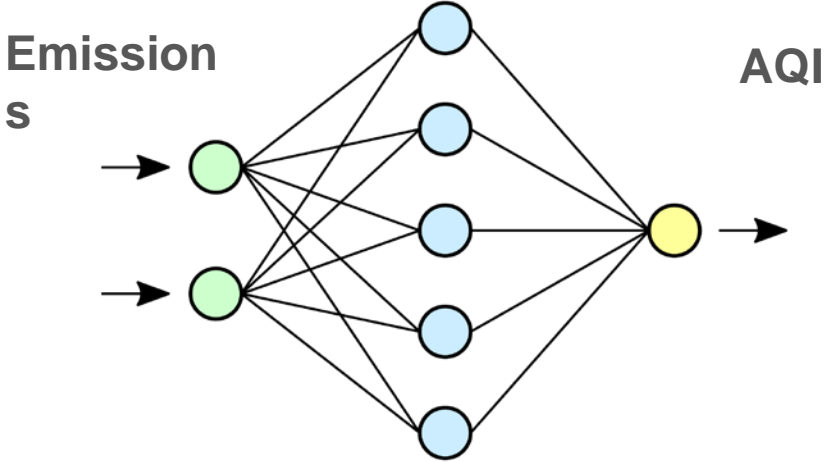
Domain
Rectangular gridded area
with 62x95 cells of 6x6 km²



MAQ Model



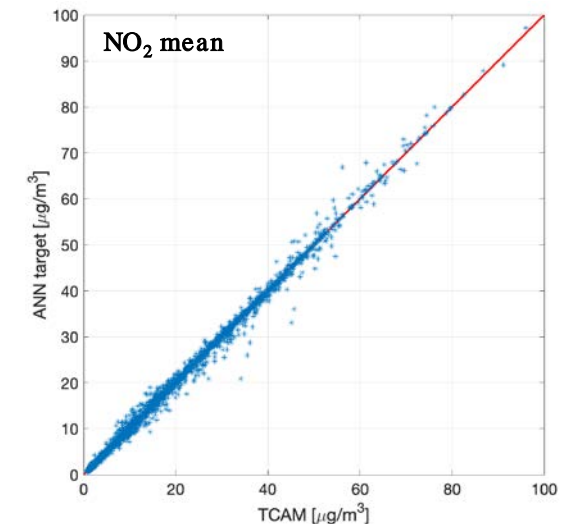
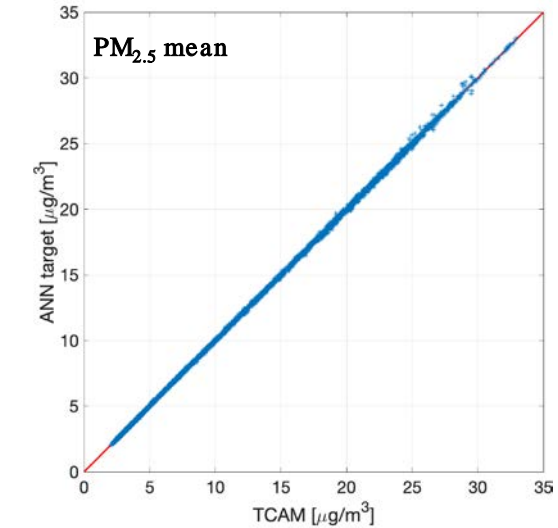
AQ surrogate models: ARTIFICIAL NEURAL NETWORKS



Source-Receptor models

	PM _{2.5} mean	NO ₂ mean
Precursors	PM ₁₀ , NO _x , NH ₃ , SO _x , VOC	NO _x , VOC
Input nodes	20	8
Layers	2	2
Hidden layer nodes	20	8
f ₁	hyperbolic tansig	hyperbolic tansig
f ₂	pure linear	pure linear

Index	PM _{2.5} mean	NO ₂ mean
Correlation	0.999	0.998
Normalized mean error	0.005	0.026
Explained variation	0.997	0.996
Standard deviation [µg/m ³]	0.106	1.107





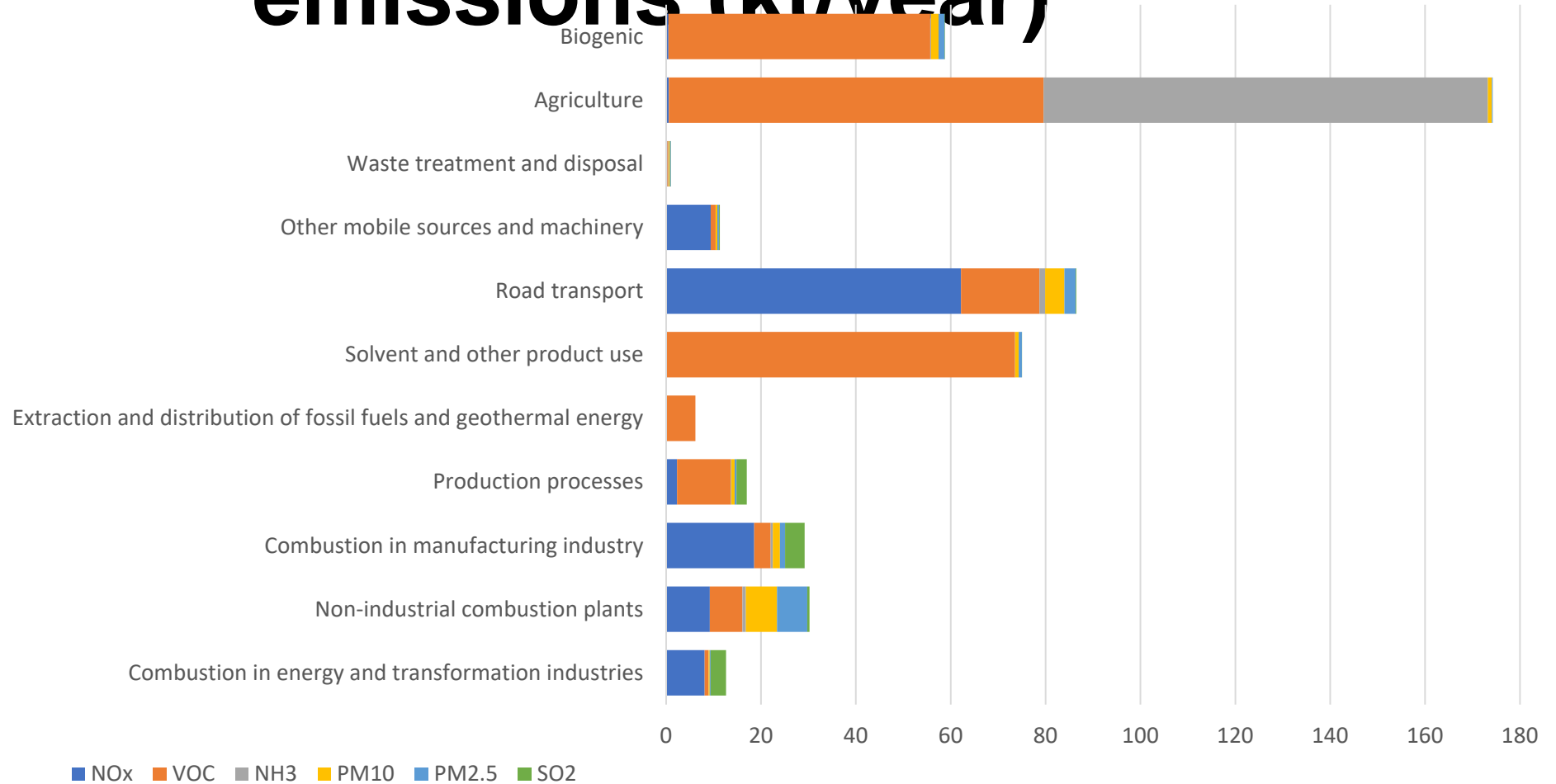
LIFE 15 IPE IT 013



The 2020 base-case scenario emissions (kt/year)



UNIVERSITY OF BRESCIA



The 2030 regional energy plan projection (CLE2030)

- Increase in energy production from renewable sources;
- Reduction of energy demand in key sectors (industry, road transportation, agriculture);
- Electric vehicles;
- Cumulative estimated cost of 24 B€ over 10 years

PREAC + PNIEC

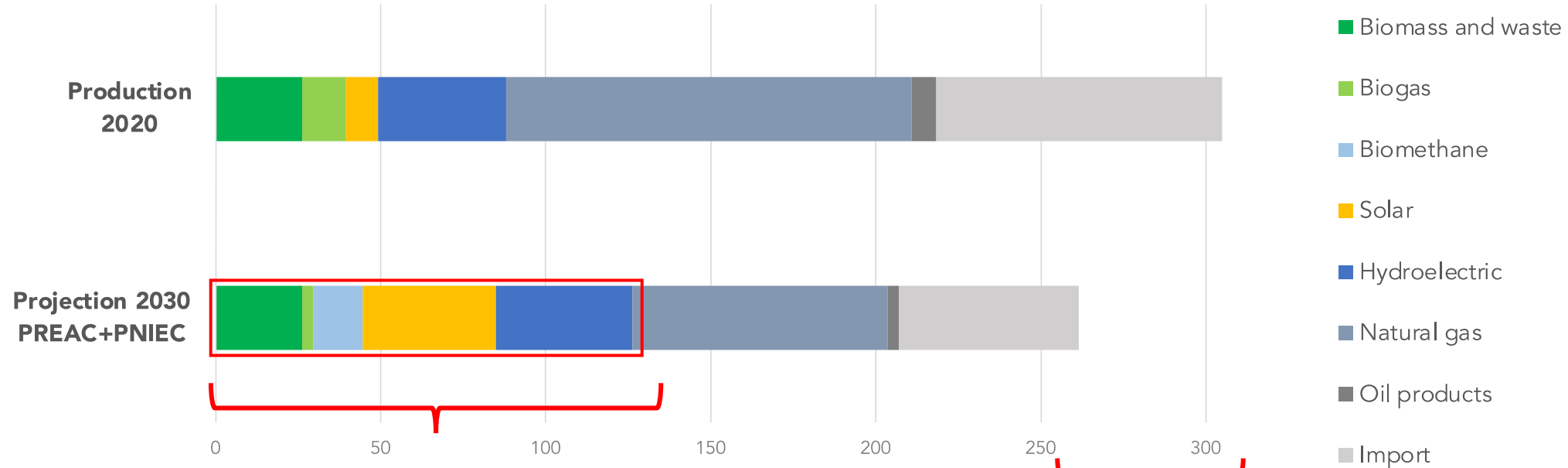
https://www.mase.gov.it/sites/default/files/archivio/pniec_finale_17012020.pdf

<https://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioRedazionale/istituzione/direzioni-general/direzione-generale-ambiente-e-clima/preac-programma-regionale-energia-ambiente-e-clima/preac-programma-regionale-energia-ambiente-e-clima>



CLE2030

Energy production (PJ)



RES equal to 39% of electric production and 56% of thermal

Energy production reduction: Energy demand

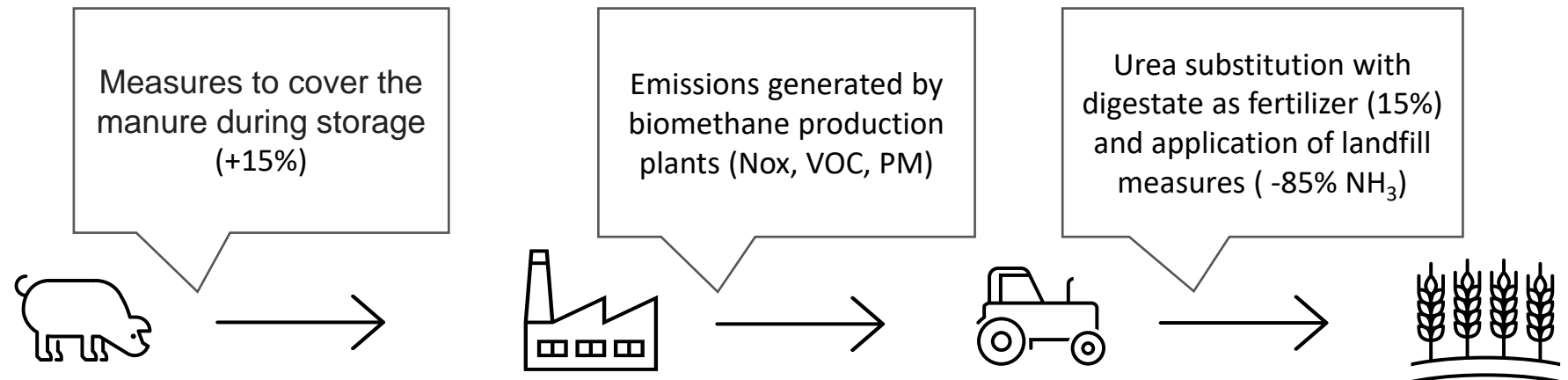
Sector	2019 demand [Mtep]	2030 projection [Mtep]	Variation
Domestic heating	423	293	-31%
Agriculture	17	17	-3%
ETS industry	180	109	-39%
Non ETS industry	121	84	-32%
Transport	201	197	-14%

CLE2030: RES

Energy source	Production in 2019 [Mtep]	2030 projection [Mtep]	Variation [%]
Photovoltaic	0.2	0.95	375%
hydroelectric	0.89	0.95	6%
Biomethane	0.01	0.72	7100%
Biogas	0.25	0.06	-75%
Bioliquid	0.02	0.02	0%
Solar thermal	0.04	0.05	25%

CLE2030: RES

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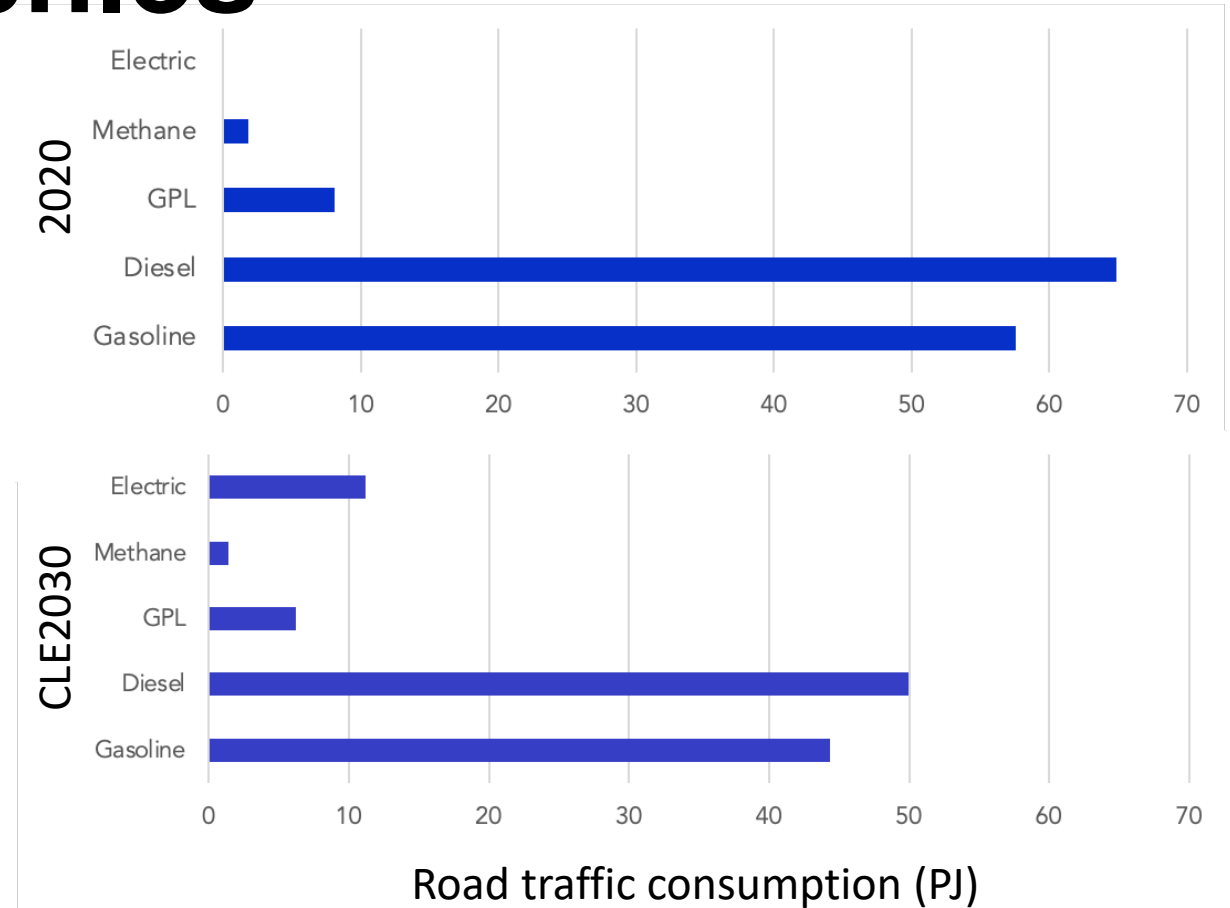


CLE2030: Electric vehicles

- Increase in cars and light duty vehicles electrification (+22%)
- Reduction in heavy duty and light duty fleet consumption by 25%

Energy required for electrification of the fleet:

$$AL_{ev} = \sum_s \sum_k \frac{AL_{s,k} \cdot \eta_{s,k}}{\eta_{ev}} \quad \begin{array}{l} s \text{ vehicle type} \\ k \text{ fuel} \end{array}$$



CLE2030: Emission reduction

Emissions variation between CLE2030 and BC2020 [%]

Macrosector	NOx	VOC	NH3	PM2.5	CO2
Combustion in energy	-35%	-34%	-36%	-32%	-44%
Non industrial combustion	-31%	-31%	-31%	-31%	-31%
Combustion in manufacturing industry	-30%	-32%	-35%	-31%	-23%
Extraction and distribution of fossil fuels	0%	1%	0%	0%	0%
Road transport	-23%	-21%	-31%	-20%	-26%
Agriculture	-3%	-3%	-4%	-3%	3%
Total	-23%	-4%	-5%	-22%	-23%

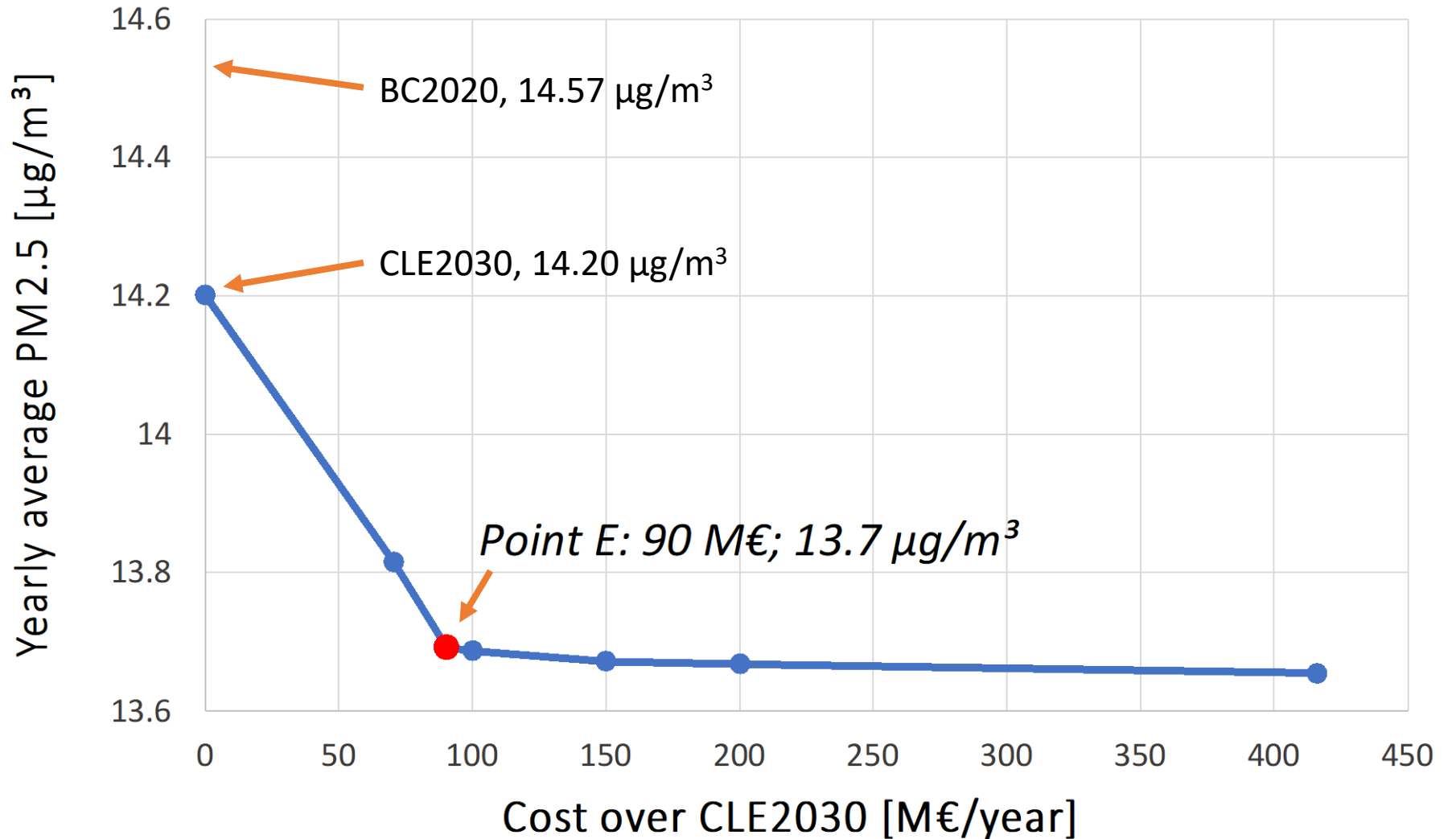
The main target of the energy plan is the reduction of CO₂ emissions

But it also has an impact on air quality

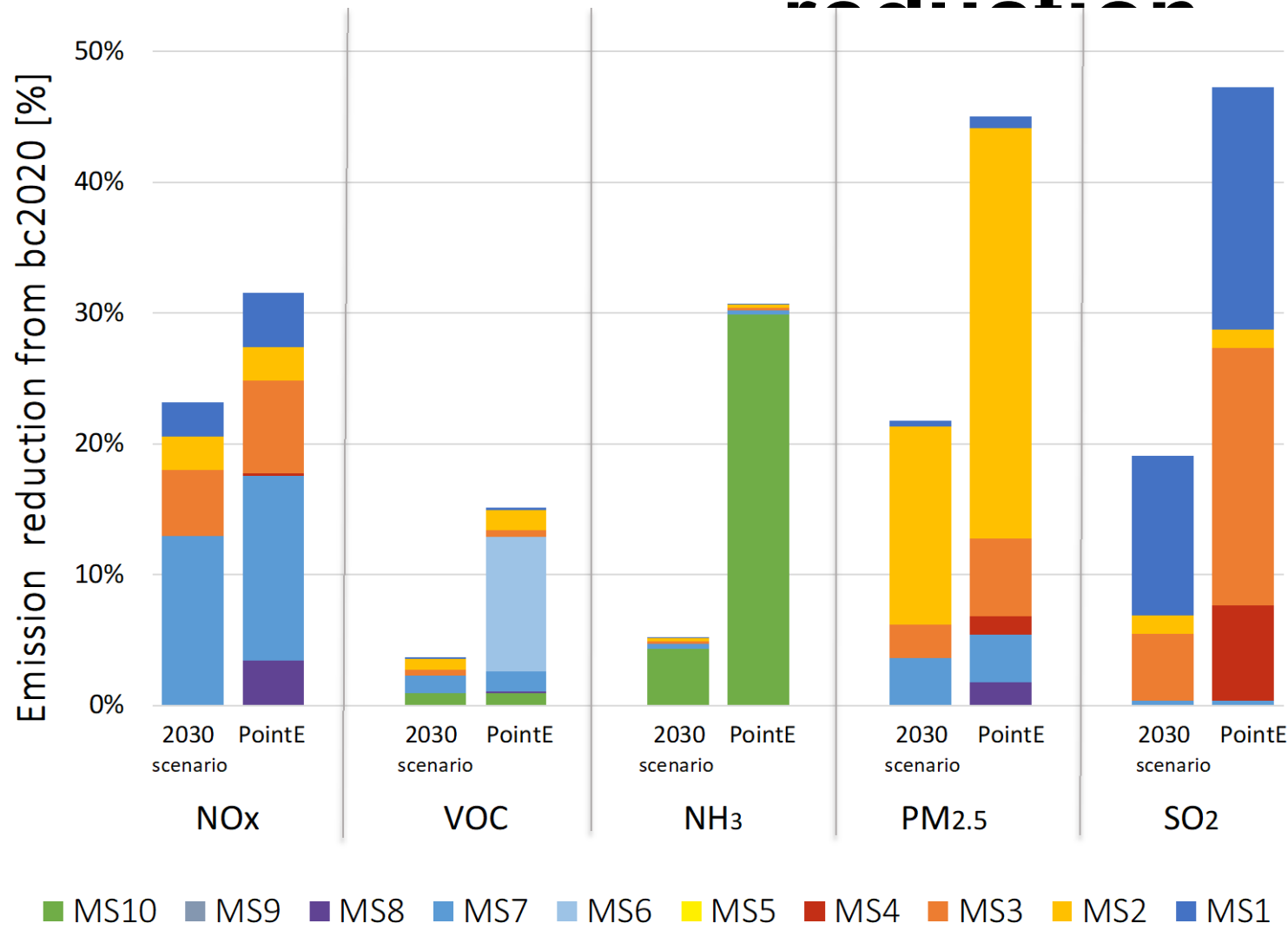
The Air Quality plan

$$\min_x [PM_{2.5}(x), C(x)]$$

s. t. $x \in X$



Results: Emission



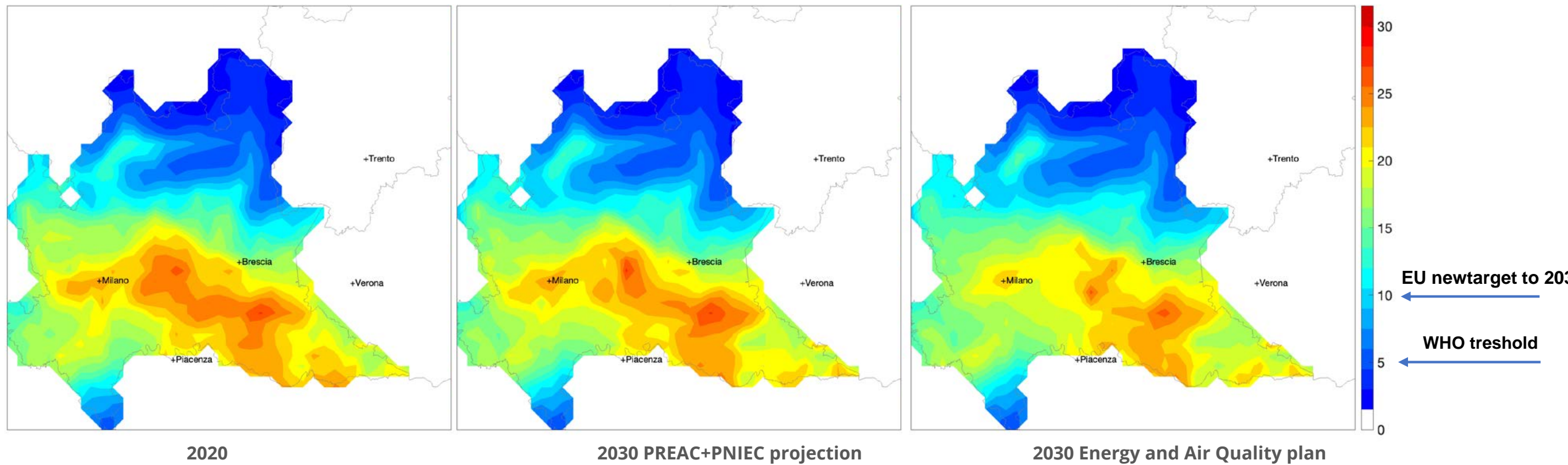
- MS1 Combustion in energy and transformation industries
- MS2 Non-industrial combustion plants
- MS3 Combustion in manufacturing industry
- MS4 Production processes
- MS5 Extraction and distribution of fossil fuels
- MS6 Solvent and other product use
- MS7 Road transport
- MS8 Other mobile sources and machinery
- MS9 Waste treatment and disposal
- MS10 Agriculture

Results: main emission reduction measures

MS	Sector	Activity	Technology	Poll.	Red. [t]
10	Cattle	liquid systems	Combination of CS_LNA*	NH ₃	8306
6	Industrial paint use	Paint use	Powder coating system	VOC	18926
1	Diesel generator	Natural gas	Switch from Euro2 to Euro3-4	NO _x	1462
3	Industrial furnaces	Biomass fuels	High efficiency deduster	PM _{2.5}	6773
*CS_LNA: Covered System and Low Nitrogen Application measures					

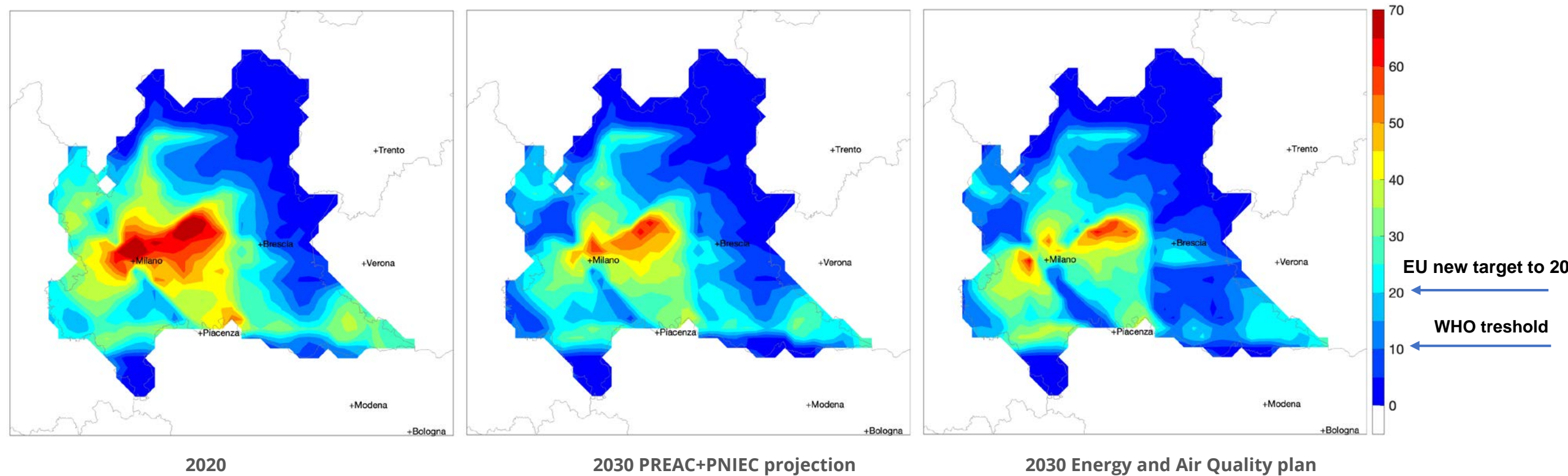
Results: PM2.5 concentrations

Yearly average PM2.5 concentration [$\mu\text{g}/\text{m}^3$]



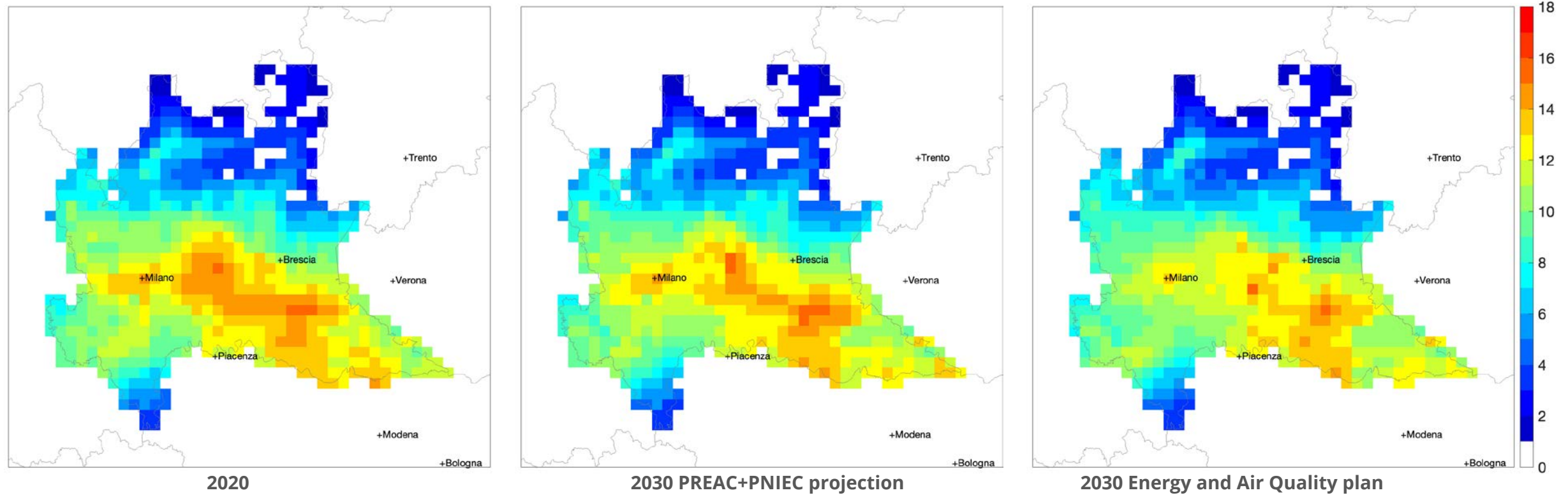
Results: NO₂ concentrations

Yearly average NO₂ concentration [$\mu\text{g}/\text{m}^3$]



Results: Health impacts

Years of Life Lost (YOLL) due to PM2.5 exposure (months/person)



Results: Health

impacts

Premature deaths variation compared to 2005



	CLE 2030	Point E
Bergamo	-33%	-47%
Brescia	-34%	-36%
Como	-55%	-60%
Cremona	-31%	-36%
Lecco	-58%	-60%
Lodi	-51%	-54%
Mantova	-13%	-19%
Milano	-52%	-59%
Monza Brianza	-60%	-64%
Pavia	-27%	-33%
Sondrio	0%	0%
Varese	-27%	-41%
Total	-41%	-47%

Conclusions

- The application of the energy plan has a main impact on CO₂, NO_x and PM_{2.5} emission reduction,
- The Air Quality plan mainly reduces VOC and NH₃ emissions.
- The energy and air quality plan provides mitigation of annual NO₂ and PM_{2.5} concentrations as a co-benefit;

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Thank you!

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