INTEGRATED ASSESSMENT MODELS: A CASE STUDY IN NORTHERN ITALY

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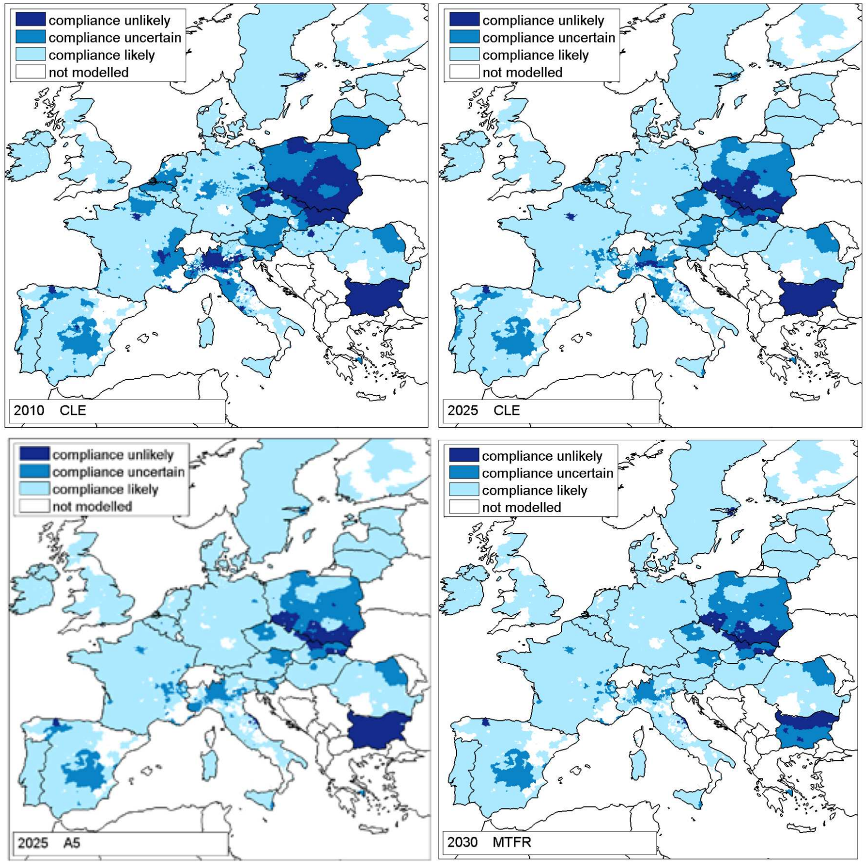
THE CHALLENGE



PM10 compliance

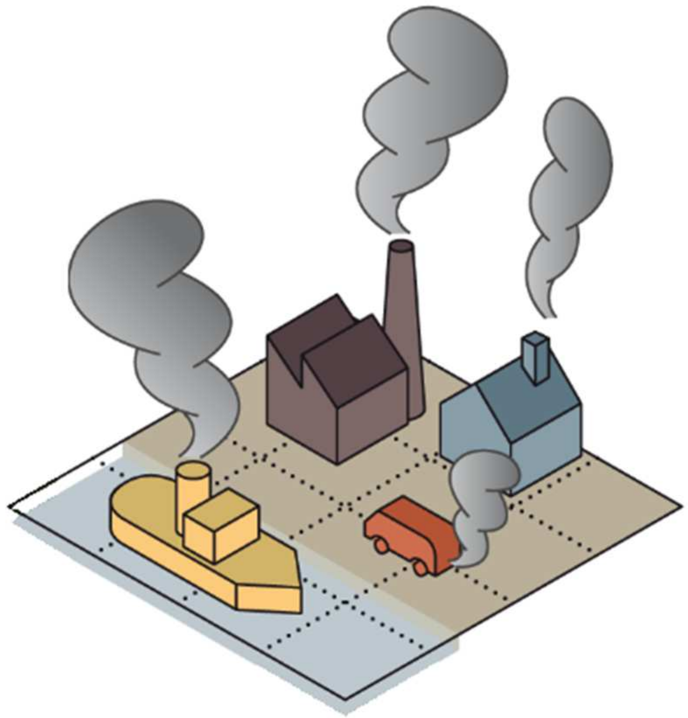
TSAP Report #10, Version 1.1, Amann et al, IIASA, March 2013

DIRECTIVE 2008/50/EC

CHAPTER IV - Article 23

Air quality plans

Where … the levels of pollutants in ambient air exceed any limit value or target value … Member States shall ensure that air quality plans are established … in order to achieve the related limit values or target values



INTEGRATED ASSESSMENT MODELS

THE IAM APPROACHES

Approach 1:
IAM assesses the impacts of proposed actions

Scenario analysis
scenario defined by

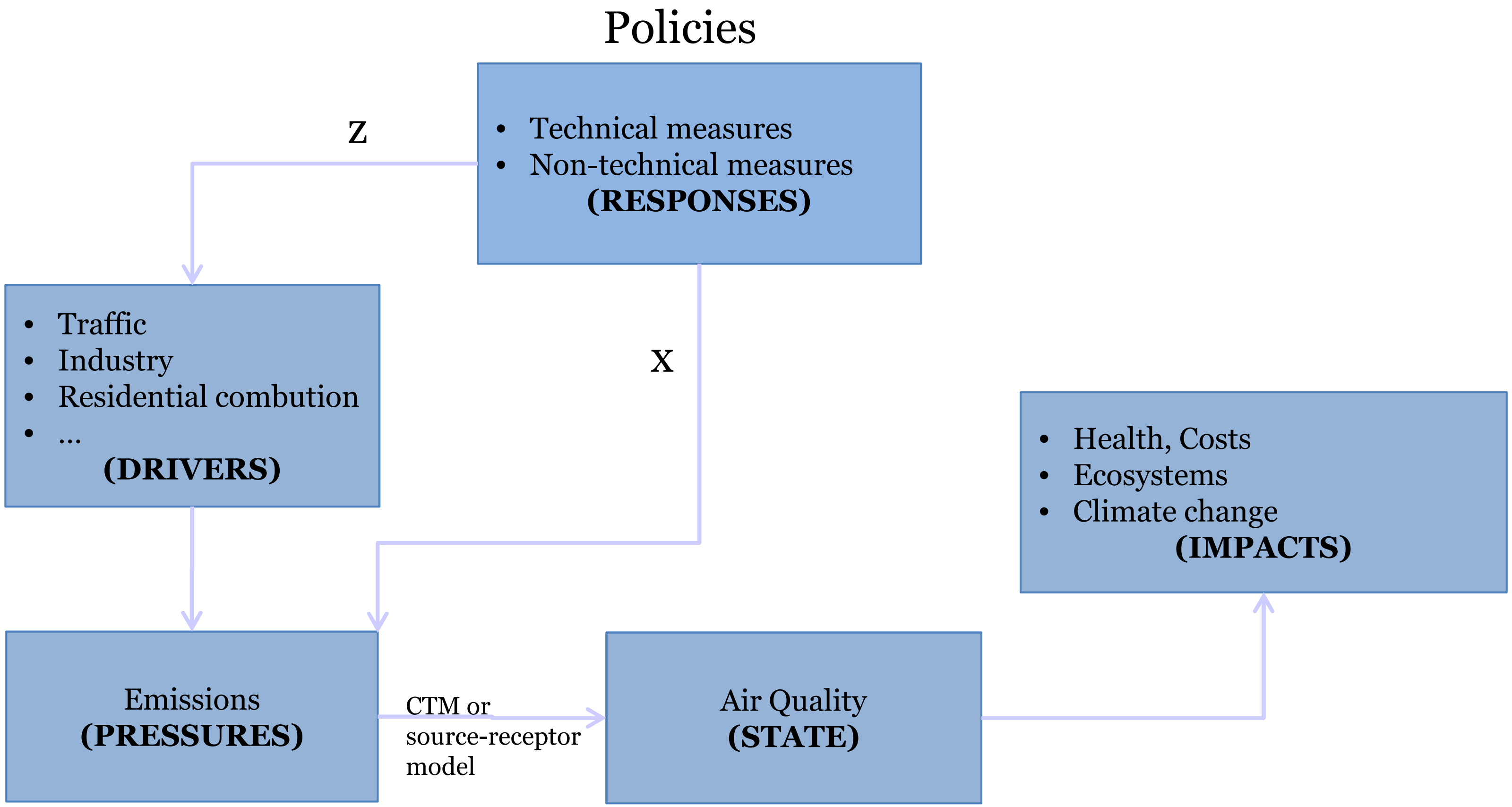
- experts
- source-apportionment

Approach 2:
IAM identifies effective emission reduction measures

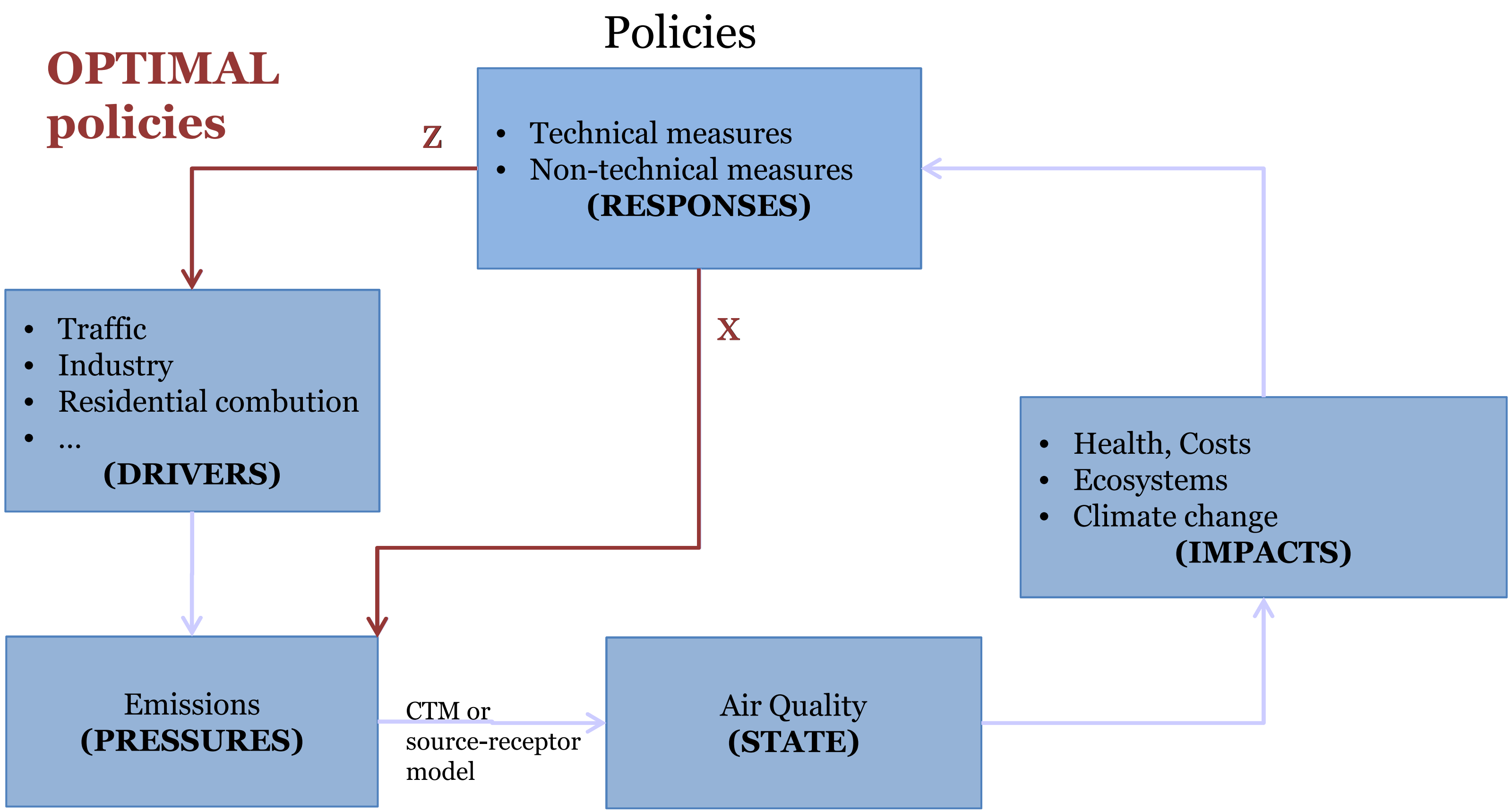
Optimization approach

- Cost effective
- Multi-objective

Approach 1: IAM assesses proposed action impacts: scenario assessment



Approach 2: IAM identifies effective emission reduction measures



2. Optimization approach

Multi-objective approach

$$\min_{x,z} J(x,z) = \min_{x,z} \left[AQI(x,z) \quad C(x,z) \right]$$

$$x \in X$$

$$z \in Z$$

Cost-effective approach

$$\min_{x,z} AQI(x,z)$$

$$x \in X$$

$$z \in Z$$

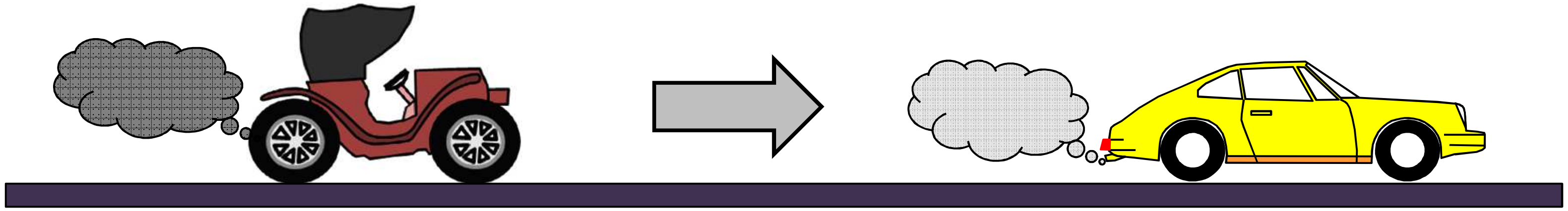
$$C(x,z) \leq L$$

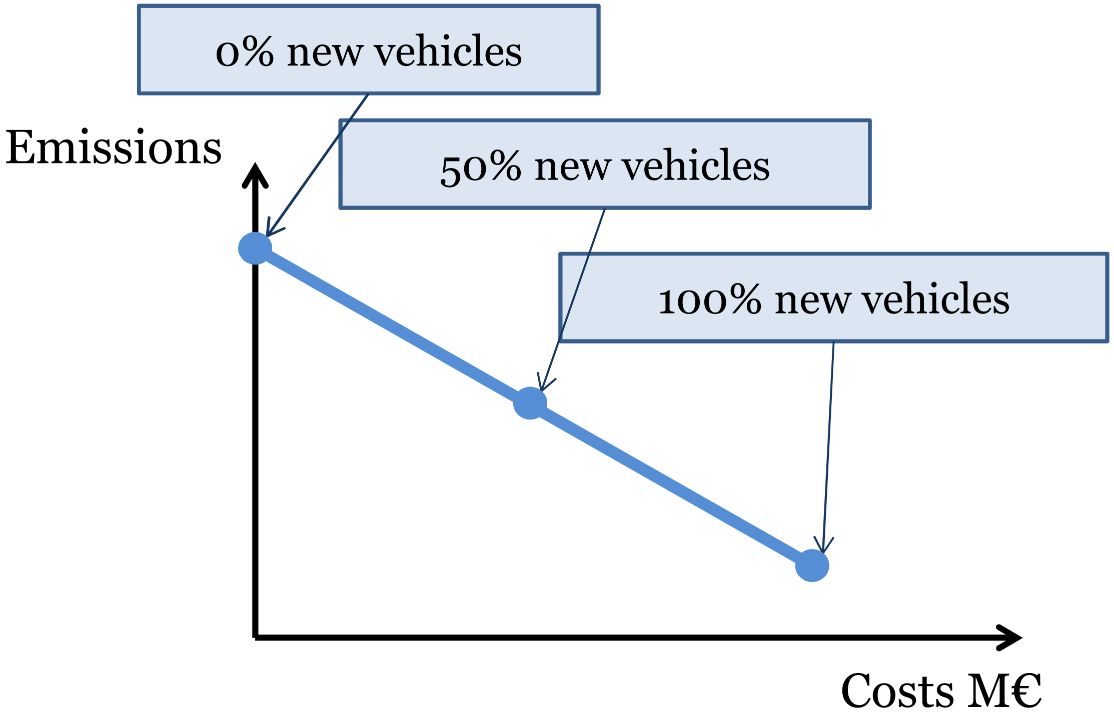
CONTR
Techn
Non-tec

A

EMISSION REDUCTION COST

Control variables: application rate





Objective function: costs

$$\min_{x,z} J(x,z) = \min_{x,z}\left[AQI(x,z) \quad C(x,z)\right]$$

$$c_{k,f} = \sum_{t \in T_{k,f}} c_{k,f,t} \cdot A_{k,f} \cdot X_{k,f,t} + \sum_{t \in T_{k,f}} c_{k,f,t} \cdot A_{k,f} \cdot Z_{k,f,t}$$

UN
for sector k, ac

A

APPLICATION

SUM OVER MACROSECTORS AND ACTIVITIES

$$C(x,z) = \sum_{k,f} c_{k,f}$$

Objective function: AQI

$$\min_{x,z} J(x,z) = \min_{x,z}\left[AQI(x,z) \quad C(x,z) \right]$$

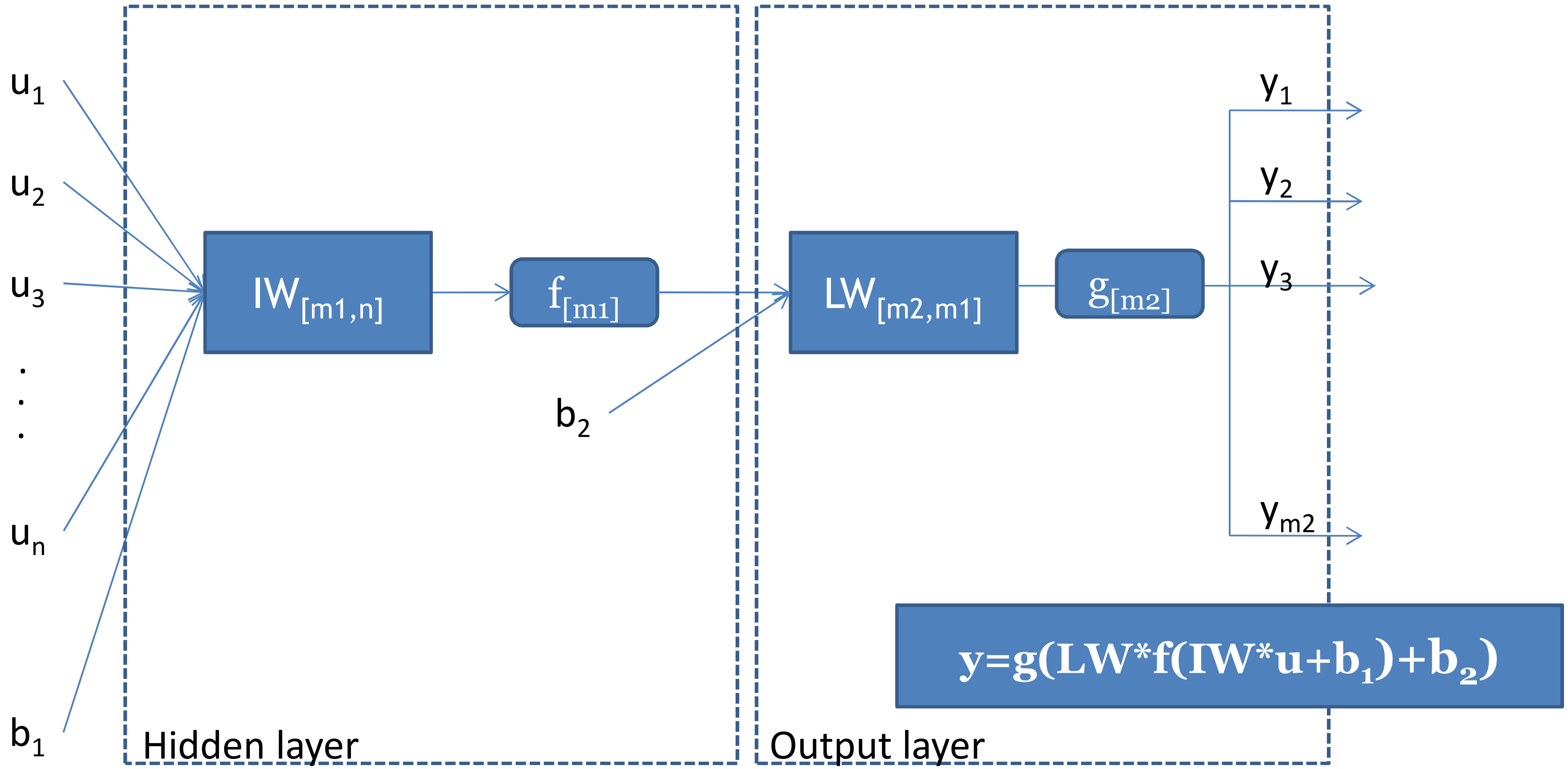
$$AQI(x,z) = f(E(x,z))$$

The function f:

- links emissions and AQI
- Non linear
- Fast air quality model
- Good performance

Artificial Neural Networks

A series of long term simulations is performed.
Artificial Neural Networks are used to derive the source-receptor relationships between emission sources and air quality indicators at given receptor sites which will be used in the optimization algorithm.



ANNs models: Inputs & Outputs

Sum of emissions over four quadrants.

- PPM10
- PPM2.5
- NH_3
- SO_2
- VOC
- NO_x

48

(=6 pollutants x 4 cells x 2 levels)

INPUTS

- meanPM10

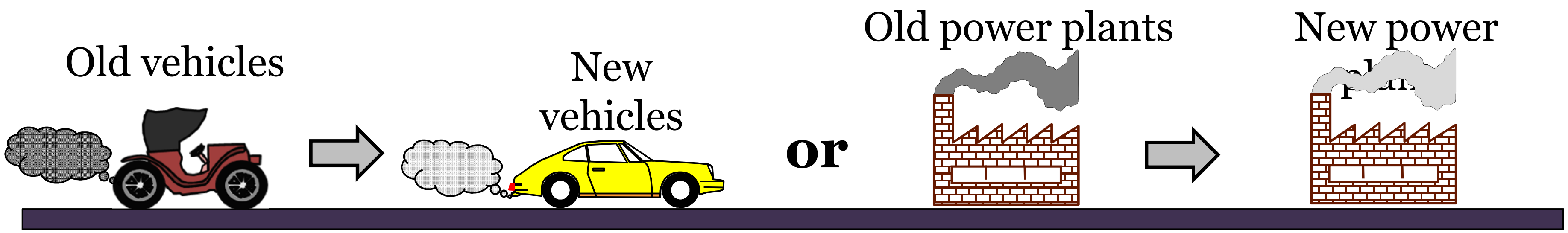
ANNs models: Design of Experiment

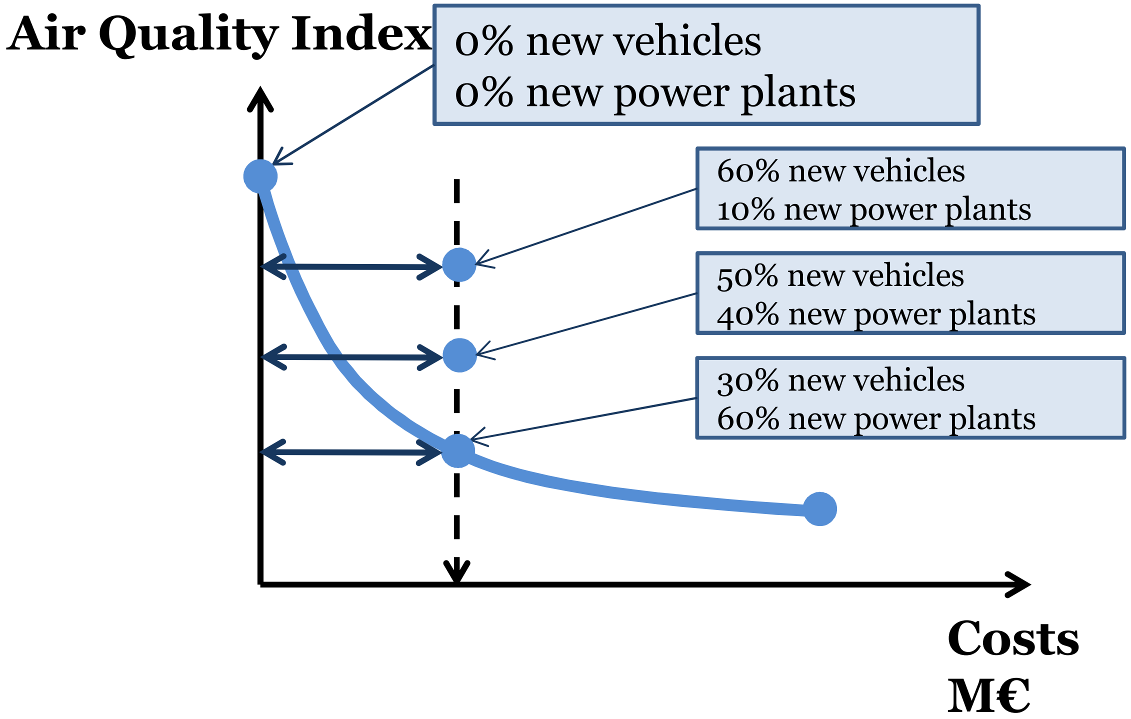
Scenarios	NOXa	VOXa	NH3a	PMa	SO2a	NOXp	VOCp	NH3p	PMp	SO2p	Boundary conditions
0	B	B	B	B	B	B	B	B	B	B	B
1	L	L	L	L	L	B	B	B	B	B	B
2	H	H	H	H	H	B	B	B	B	B	B
3	H	L	L	L	L	B	B	B	B	B	B
4	L	H	L	L	L	B	B	B	B	B	B
5	L	L	H	L	L	B	B	B	B	B	B
6	L	L	L	H	L	B	B	B	B	B	B
7	L	L	L	L	H	B	B	B	B	B	B
8	H	H	L	L	L	B	B	B	B	B	B
9	H	L	H	H	H	B	B	B	B	B	B
10	H	L	H	L	L	B	B	B	B	B	B
11	H	L	H	L	H	B	B	B	B	B	B
12	B	B	B	B	B	L	L	L	L	L	B
13	B	B	B	B	B	H	H	H	H	H	B
14	B	B	B	B	B	H	L	L	H	H	B
15	B	B	B	B	B	L	L	L	L	H	B
16	B	B	B	B	B	H	L	L	L	H	B
17	H	H	H	H	H	H	H	H	H	H	B
18	H	L	H	H	H	H	L	L	H	H	B
19	L	L	L	L	H	L	L	L	L	H	B
20	H	L	H	L	H	H	L	L	L	H	B
21	H	H	L	L	L	H	H	L	L	L	B

TCAM deterministic modelling system simulations

B = cle2010
H = mfr2020
L = average of B,H

Optimization





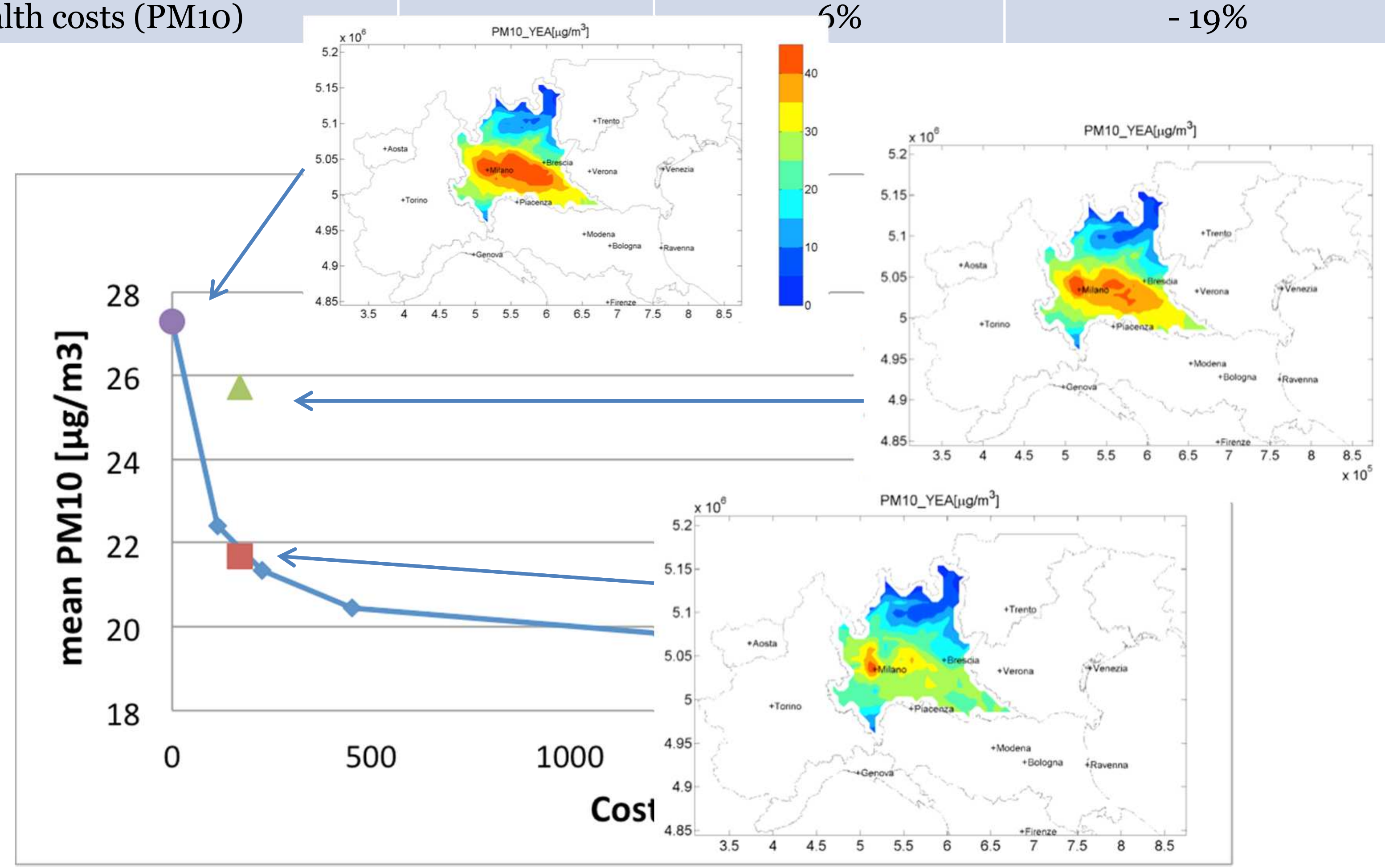
This optimumAQI can be computed for each cost, it gives a optimal curve called “Pareto curve”.

Traffic scenario analysis

- Vehicle fleet: new EURO standard
- Efficiency Measures:
  - bus investment
  - bicycle path
  - lower speed on highway

Scenario analysis vs optimization

Impacts	CLE	Traffic scenario	Optimized scenario
Emission reduction costs	0 €	171 M€	171 M€
PM10 [µg/m3]	10-50	- 6%	- 21%
Health costs (PM10)	[illegible]	6%	- 19%



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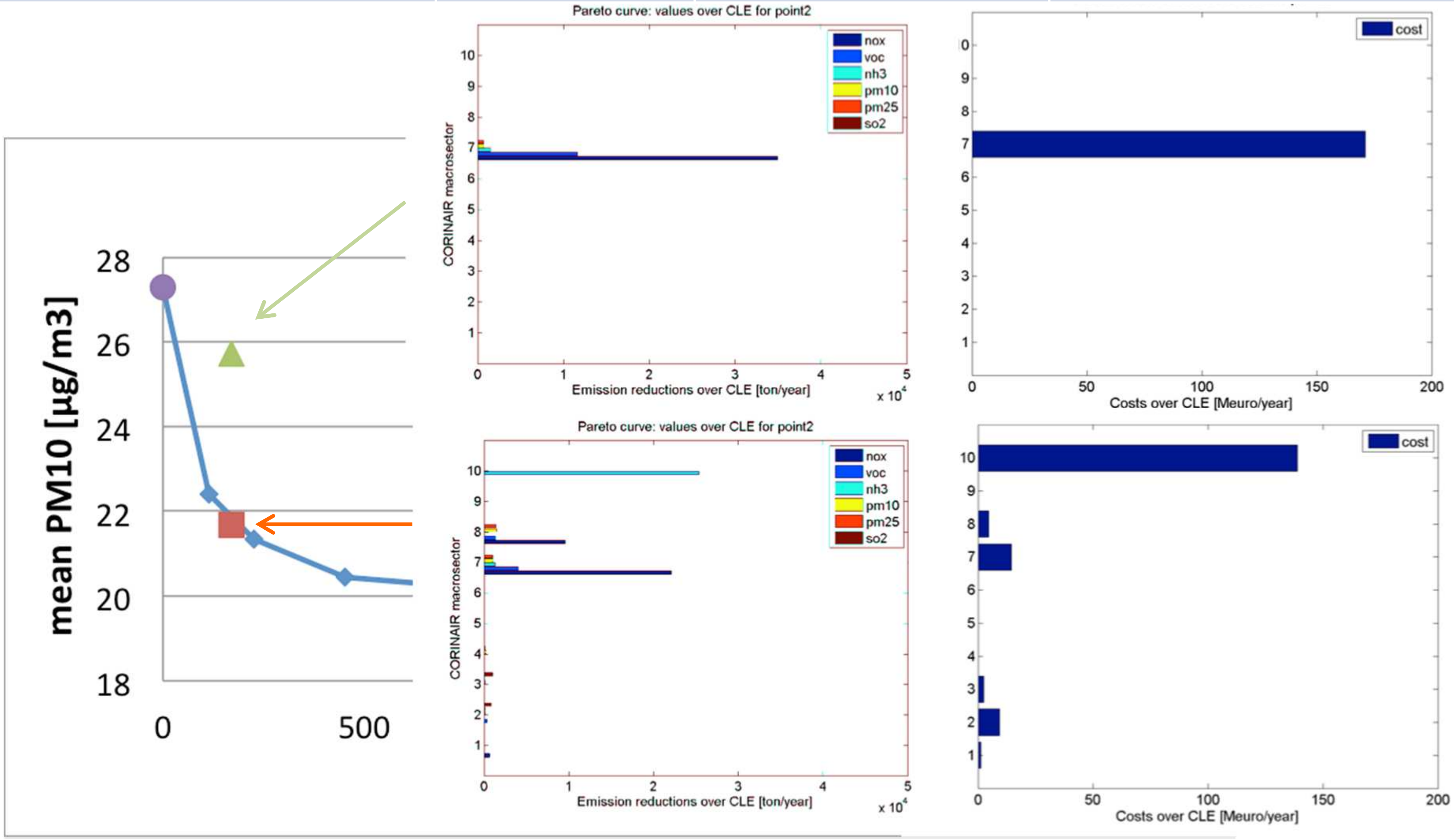
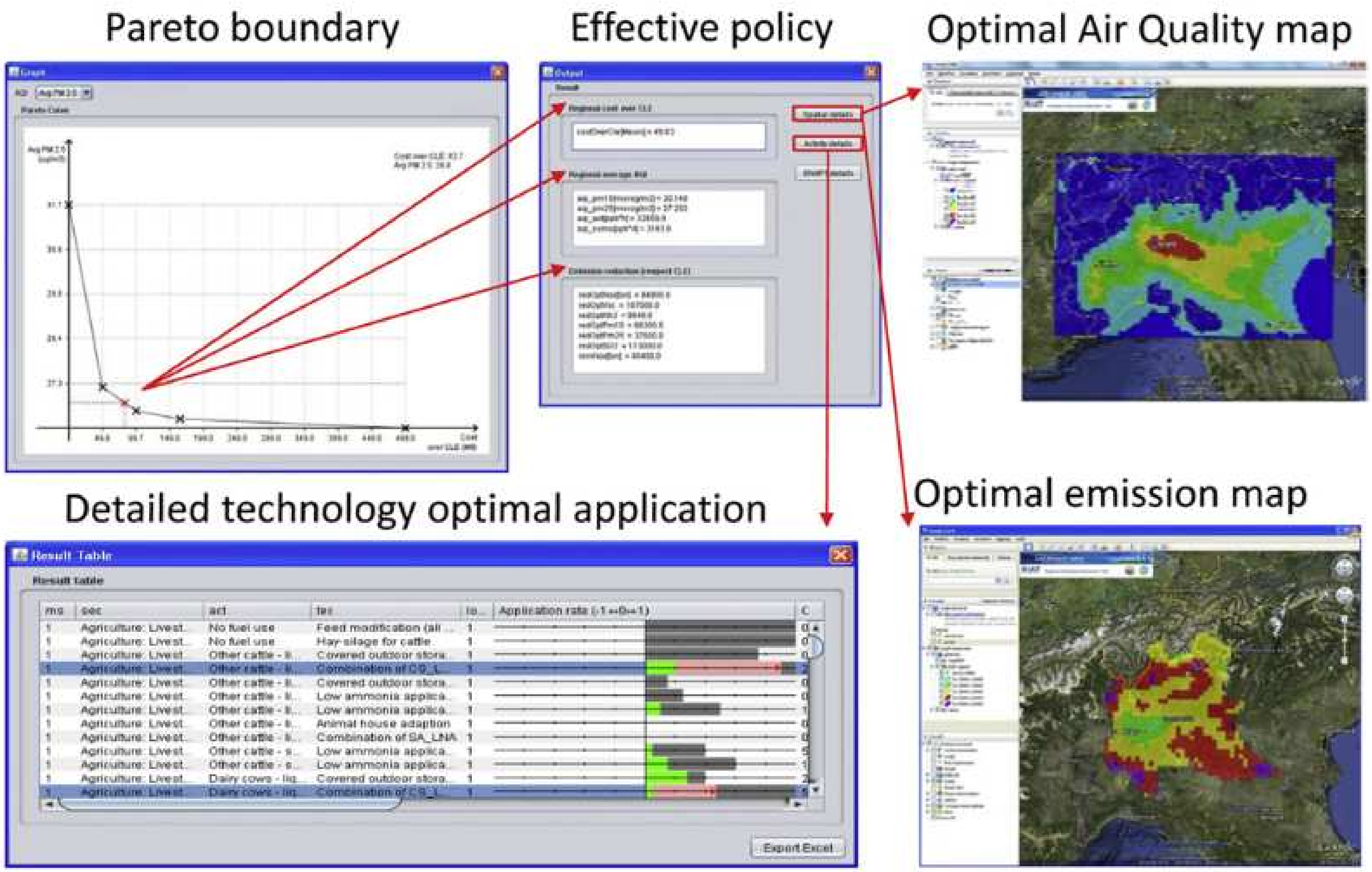


Example of RIAT results



Conclusions

- Scenario analysis approach:
  - allows to assess the variations of AQI due to the application of a set of policies chosen by the user;
  - the measures that can be implemented are hundreds; does not guarantee that the most efficient combination of measures is identified.

- The Multi-Objective approach:
  - optimizes a number of objectives simultaneously;
  - allows to find the most efficient set of measures that guarantees to achieve the highest reduction of secondary pollution over the domain , at minimum costs.

Thank you for your attention

•Carnevale, C.; Finzi, G.; Pederzoli, A.; Turrini, E.; Volta, M.; Guariso, G.; Gianfreda, R.; Maffeis, G.; Pisoni, E.; Thunis, P.;Markl-Hummel, L.; Perron, G.; Blond, N.; Weber, C.; Clappier, A.; Dunardin, V.; in press. "Exploring trade-offs between air pollutants through an Integrated Assessment Model".

•C. Carnevale, G. Finzi, E. Pisoni, M. Volta, G. Guariso, R. Gianfreda, G. Maffeis, P. Thunis, L. White, G. Triacchini (2012). An integrated assessment tool to define effective air quality policies at regional scale, Environmental Modelling and Software, 38, 306-315.

•Carnevale, C., Finzi, G., Pisoni, E., & Volta, M. (2009). Neuro-fuzzy and neural network systems for air quality control. Atmospheric Environment, 43, 4811-4821.