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LOW EMISSION ROAD TRANSPORT SCENARIOS: AN INTEGRATED ASSESSMENT OF ENERGY DEMAND, AIR QUALITY, GHG EMISSIONS AND COSTS

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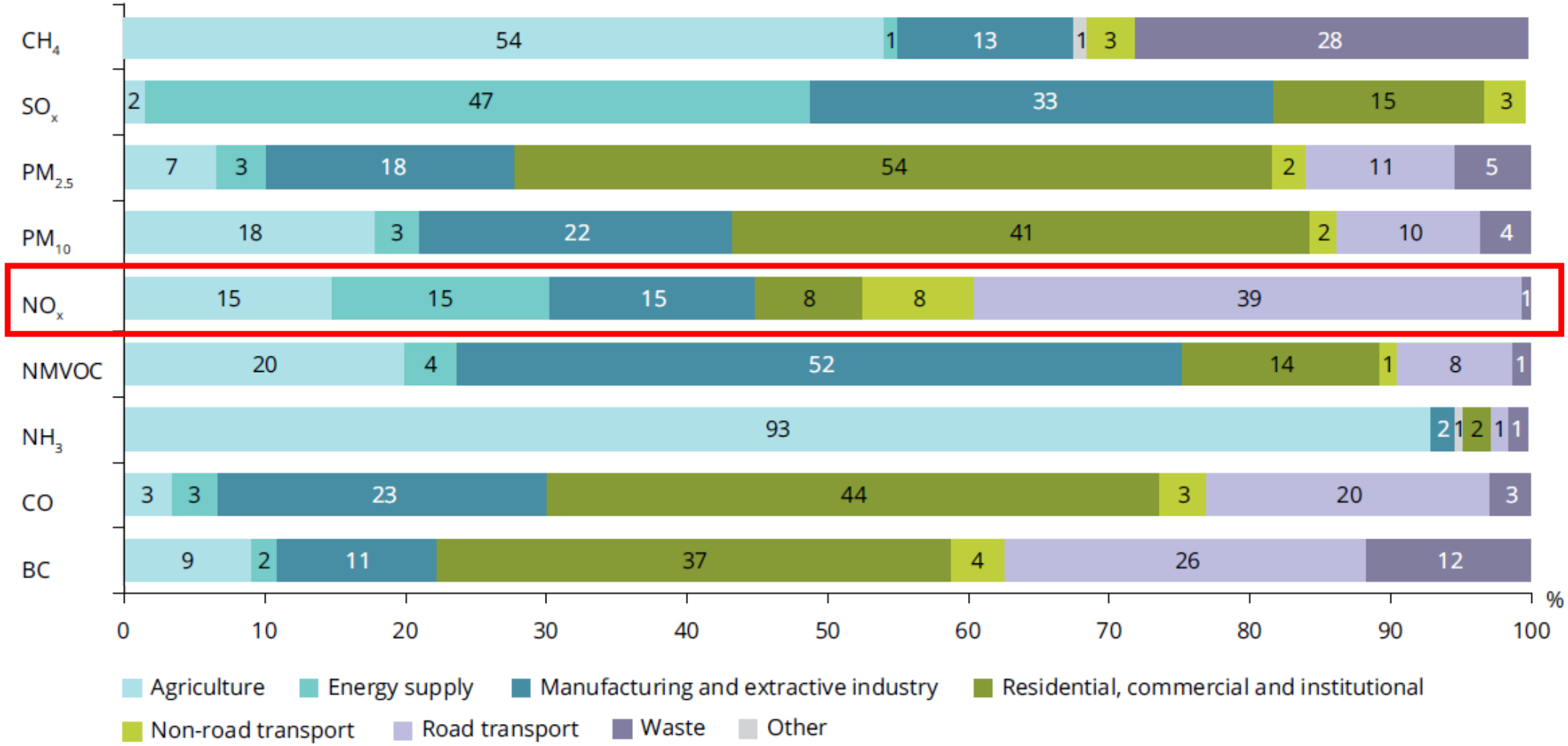
Emissions in Europe - 2018



Source: EEA Report No 09/2020 – Air Quality in Europe 2020 Report

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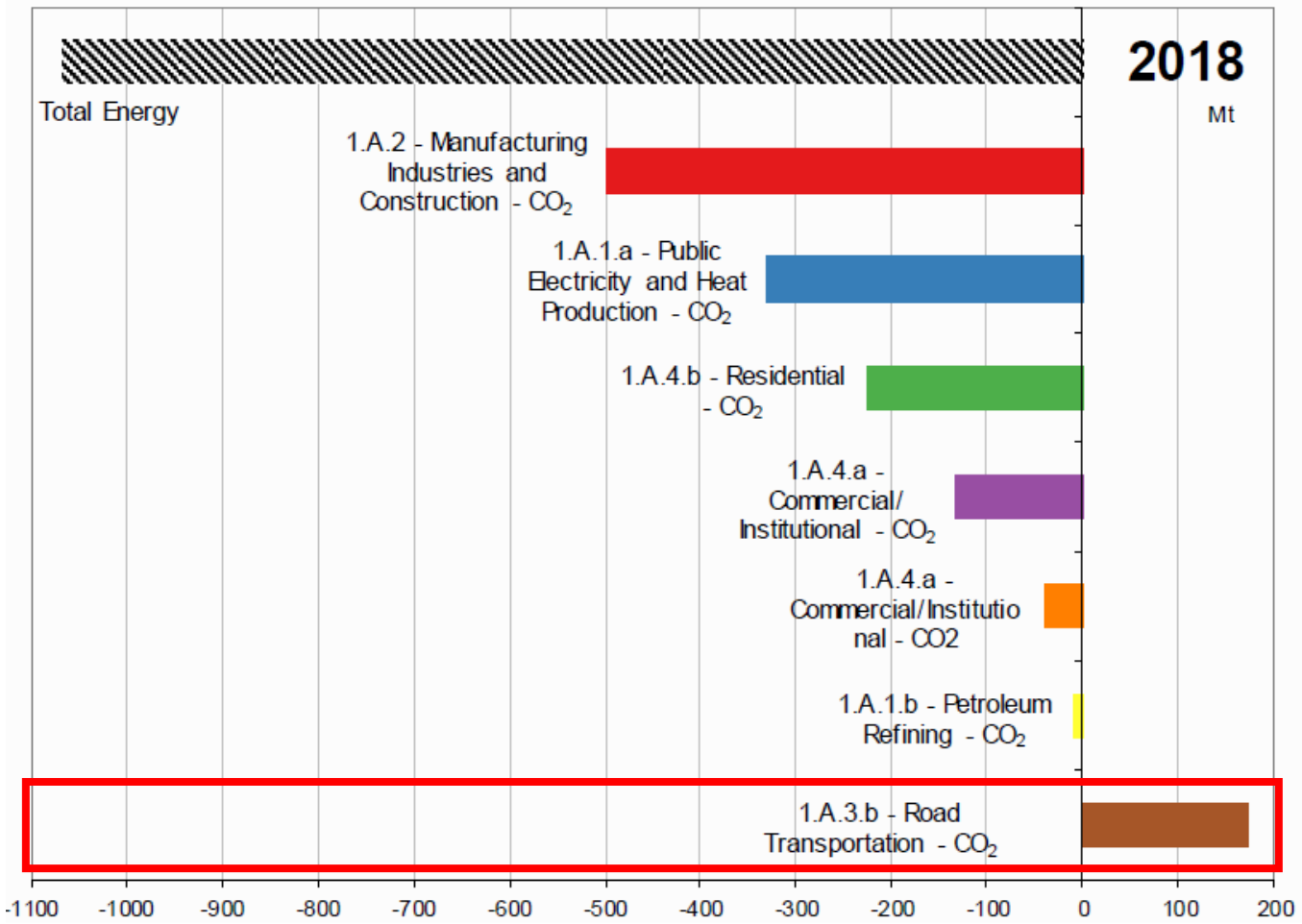
Emissions in Europe - 2018



Source: EEA/PUBL/2019/051 - Annual European Union greenhouse gas inventory 1990–2018 and inventory report 2020

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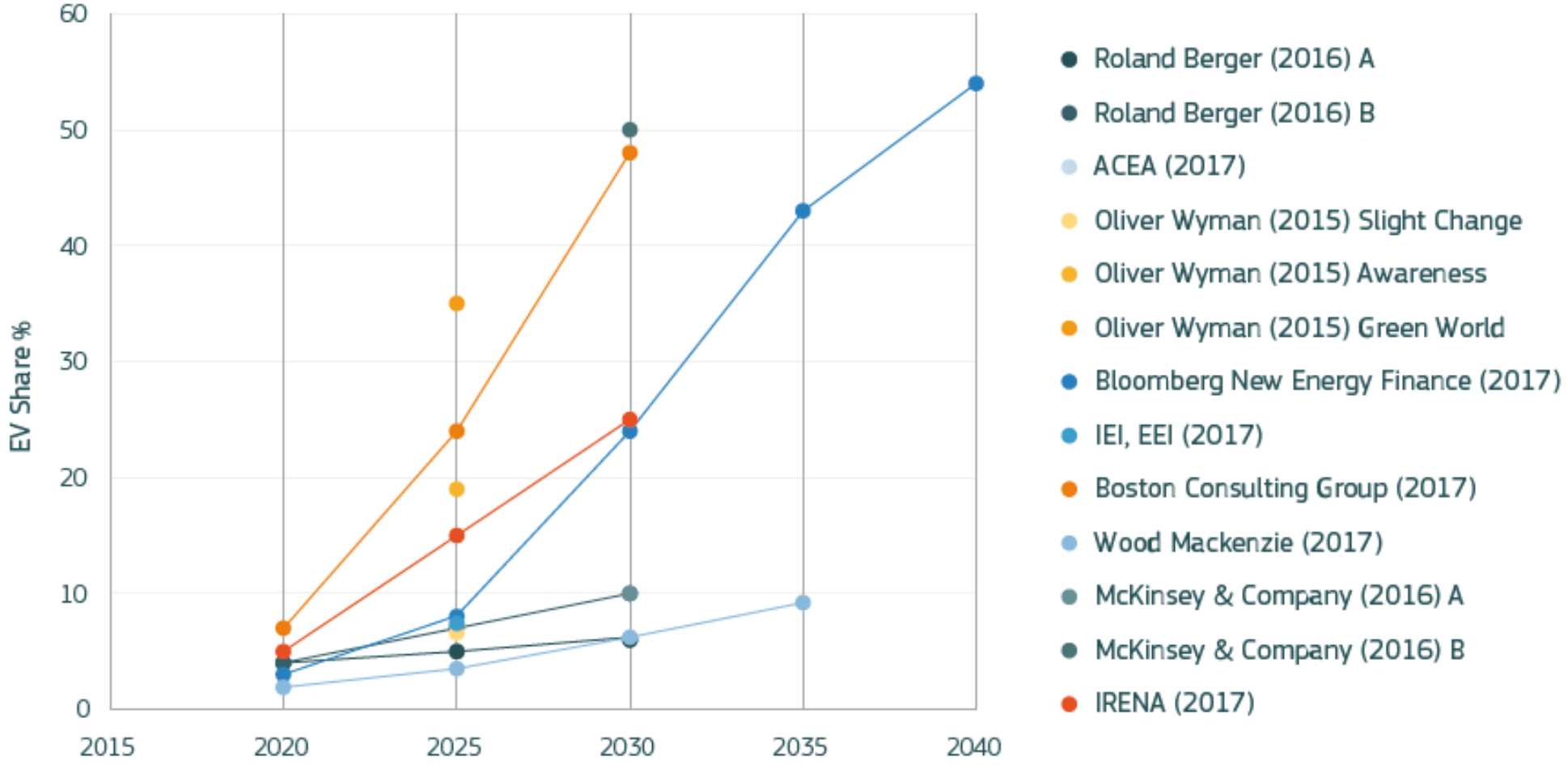
Electrification of the vehicle fleet



Range of global sales projections for BEV/PHEV until 2040 (as % of EVs of the total vehicles sold) – source: THE FUTURE OF ROAD TRANSPORT European Commission 2019

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Identifying low emission road transport scenarios: multi-objective decision problem

$$\min_{\mathbf{x}} f(\mathbf{x}) = \min_{\mathbf{x}} [AQI_{PM2.5}(\mathbf{x}), AQI_{NO2}(\mathbf{x}), TC(\mathbf{x}), GHG(\mathbf{x})]$$

$\mathbf{x} \in X$

Air Quality Indexes

Greenhouse gases emissions

Total cost

Control variables $\mathbf{x} = \begin{bmatrix} \mathbf{r} \\ \mathbf{nr} \end{bmatrix}$

r: renewable sources electricity production

nr : non-renewable sources electricity production

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Identifying low emission road transport scenarios: multi-objective decision problem

$$\min_{\mathbf{x}} f(\mathbf{x}) = \min_{\mathbf{x}} \left[AQI_{PM2.5}(\mathbf{x}), AQI_{NO2}(\mathbf{x}), TC(\mathbf{x}), GHG(\mathbf{x}) \right]$$

$\mathbf{x} \in X$

Control variables $\mathbf{x} = \begin{bmatrix} \mathbf{r} \\ \mathbf{nr} \end{bmatrix}$

r: renewable sources electricity production

nr : non-renewable sources electricity production

Total production $= \sum_j r_j + \sum_k nr_k$

Constraints

$$\sum_{j=1}^{nr} r_j \geq \alpha \cdot (d - u)$$

$$lb_j^r \leq r_j \leq ub_j^r$$

$$lb_k^n \leq nr_k \leq ub_k^n$$

→ Domain specific
Depends on European and National legislation

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Identifying low emission road transport scenarios: multi-objective decision problem

Electricity demand

$$d = d_0 + \Delta d$$

Increase in electricity demand

$$\Delta d = u + \sum_{i}^{n_t} \Delta x_i$$

Variation in electricity production

$$\Delta x_i = \frac{\varepsilon_i \cdot \Delta al_T}{\eta_e \cdot \eta_{pd,i}}$$

Variation of activity level in road transport

$$\Delta al_T = \sum_{s \in S} \sum_{z \in Z} al_{s,z} \cdot \eta_z$$

Constraints

$$\sum_{j=1}^{n_r} r_j \geq \alpha \cdot (d - u)$$

$$lb_j^r \leq r_j \leq ub_j^r$$

$$lb_k^n \leq nr_k \leq ub_k^n$$

Electricity distribution and production efficiency

Electric engine efficiency

Internal combustion engine efficiency

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Mulit-objective problem solving

→ An **enumeration approach** is applied discretizing the decision variables in the feasible set

→ A set of **40 scenarios** is identified varying the **electricity production** distribution in the **feasible set** (r_j, nr_k)

→ The problem solutions are the **non-dominated scenarios** in the objective spaces.

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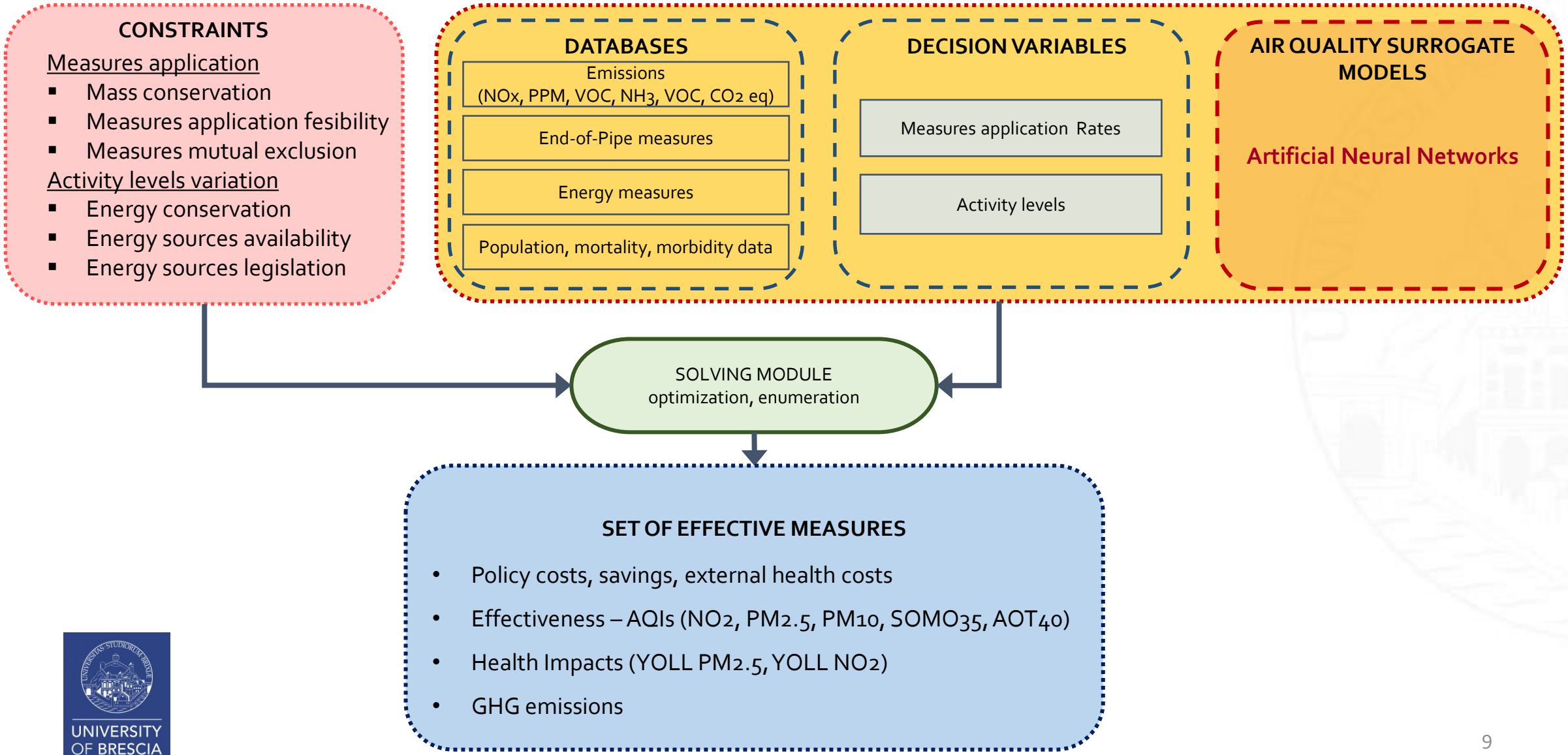
MAQ (Multi-dimensional Air Quality) System



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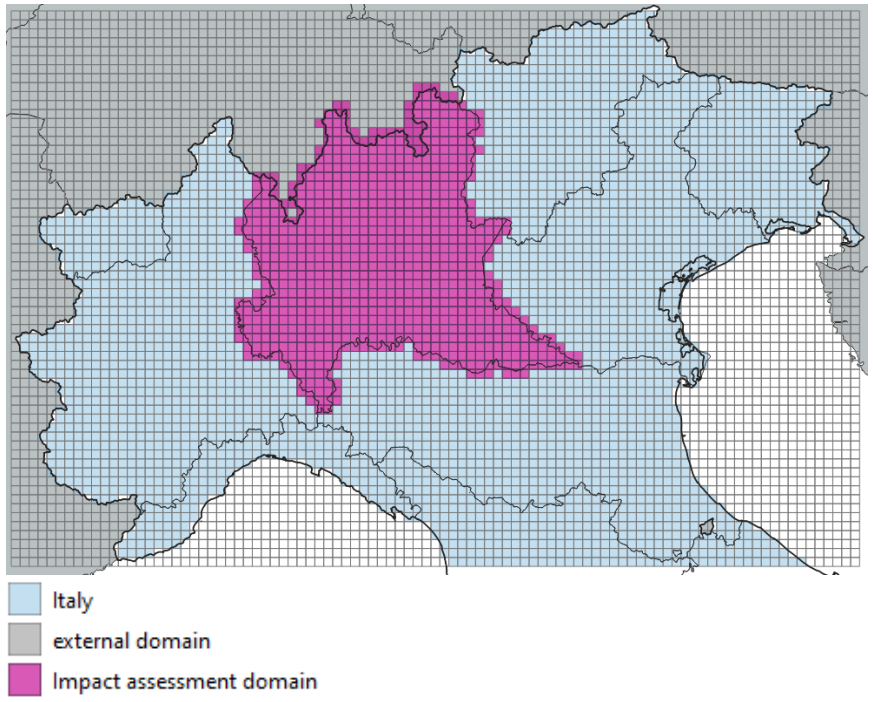
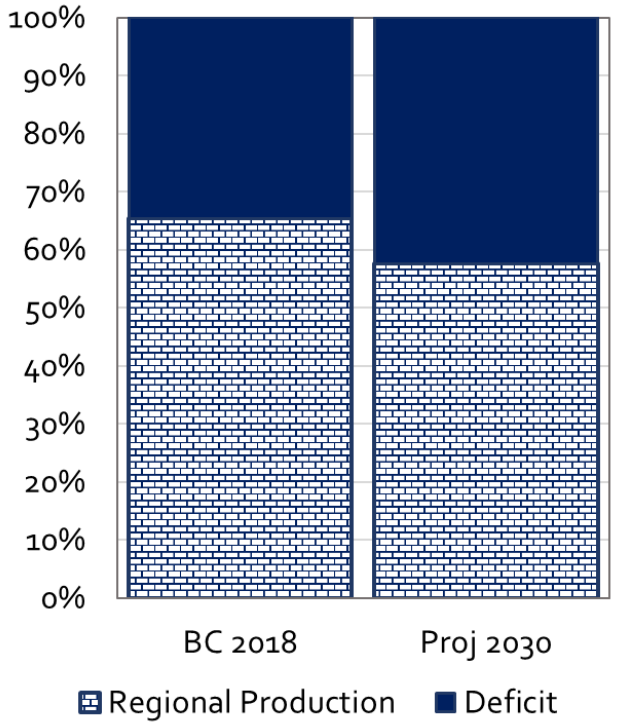
Electricity demand and production: basecase and projection

DOMAIN

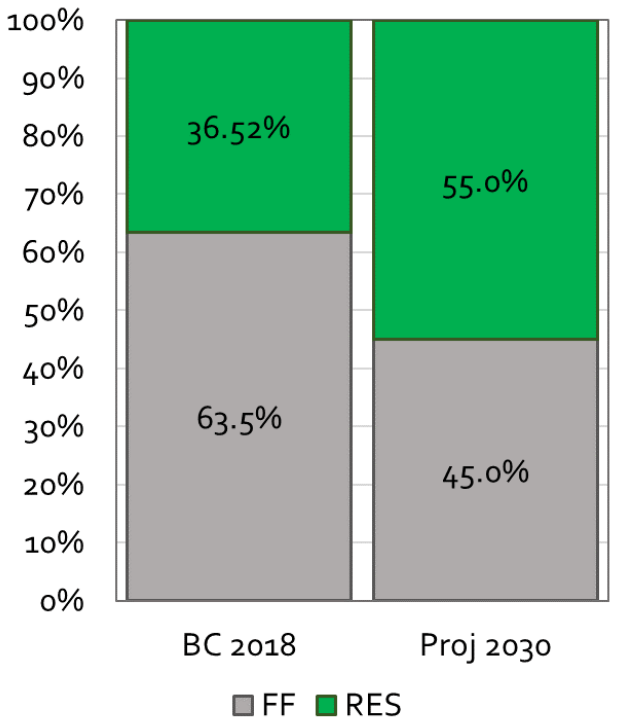


	RES objective 2030
Electricity production	55%
Thermal energy	33.9%
Transport	22%
Final gross energy consumption	30%

ELECTRICITY DEMAND



ELECTRICITY PRODUCTION



Source: Adapted from PNIEC (Piano Nazionale Integrate Energia e Clima), TERNA and GSE data

Low emission road transport policy

- Light duty vehicles, cars and mopeds are shifted to electricity;
- Heavy duty vehicles are powered by biomethane.

Fuel	Activity Level [PJ]			η [-]
	Cars	LDV	Mopeds	
Diesel	97.5	9.8	0.0	0.4
Gasoline	27.9	0.6	0.7	0.3
LPG	20.6	0.0	0.0	0.3
Natural gas	3.7	0.2	0.0	0.3
Gross electric fleet energy	160.9			0.9
Net energy considering engine efficiency (ICE and electric)	65.6			
Energy demand considering 46% electricity production and distribution efficiency	**142.6**			

Fuel	Activity Level [PJ]	η [-]
	HDV	
Diesel	66.2	0.4
Natural gas	0.1	0.3
Total	66.4	
Net energy considering engine efficiency on biomethane	**88.4**	

INCREASE IN ELECTRICITY DEMAND

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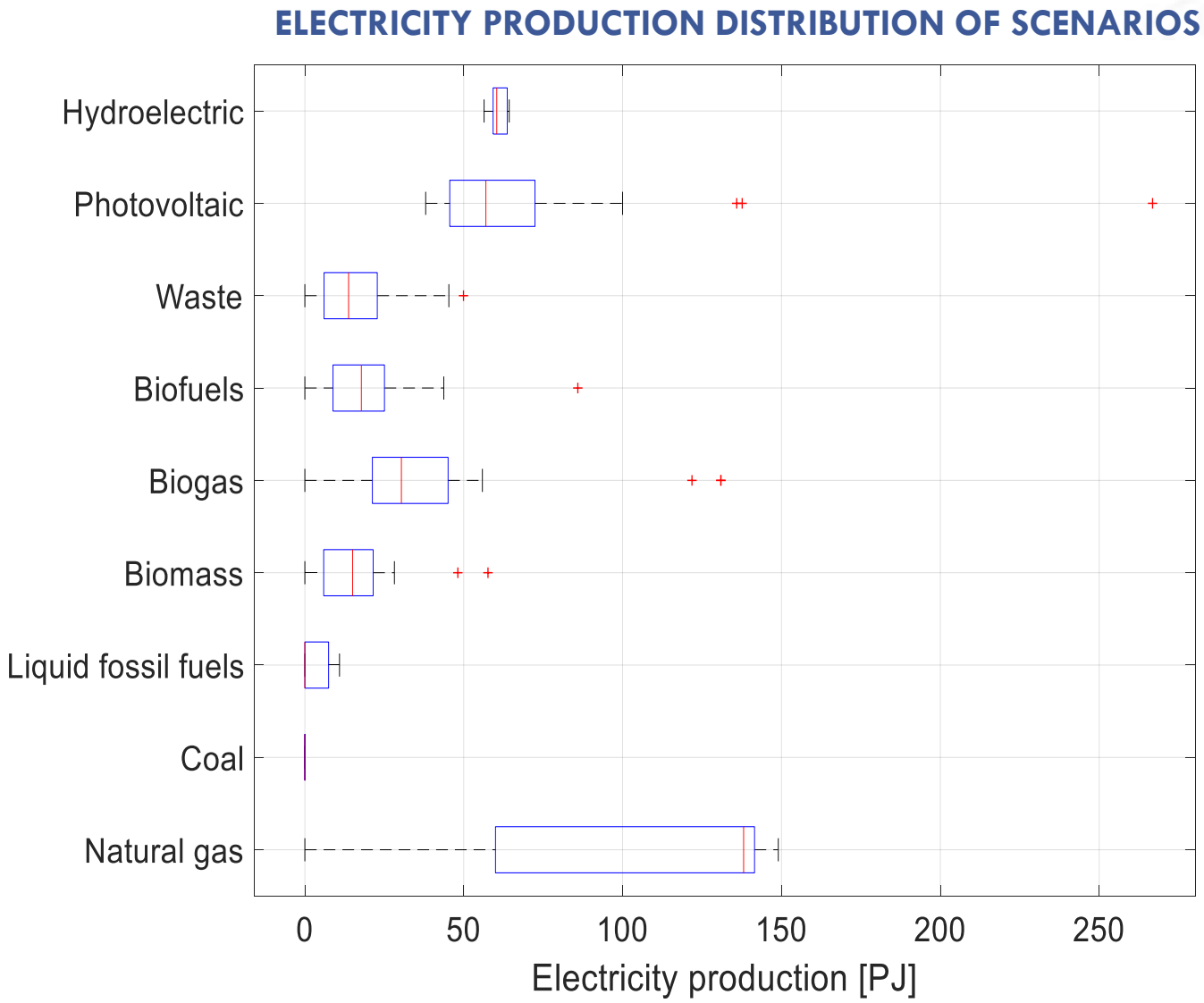
Problem solving

→ Scenarios are computed varying the electricity production distribution in the feasible set (r_j, nr_k)



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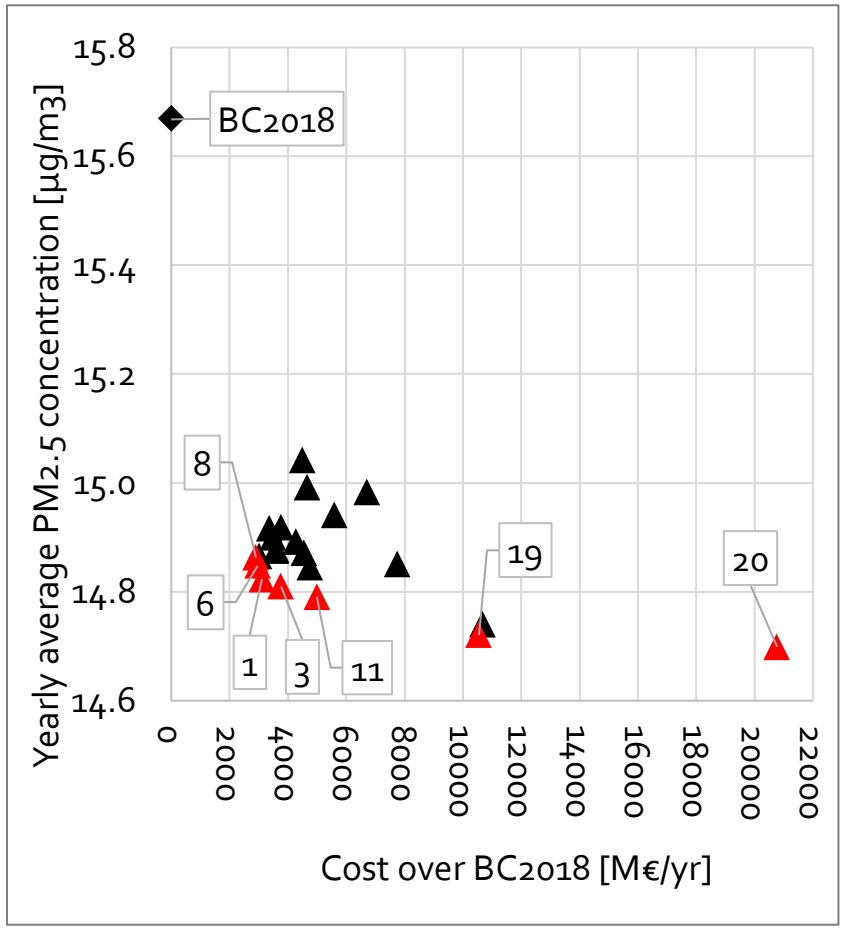
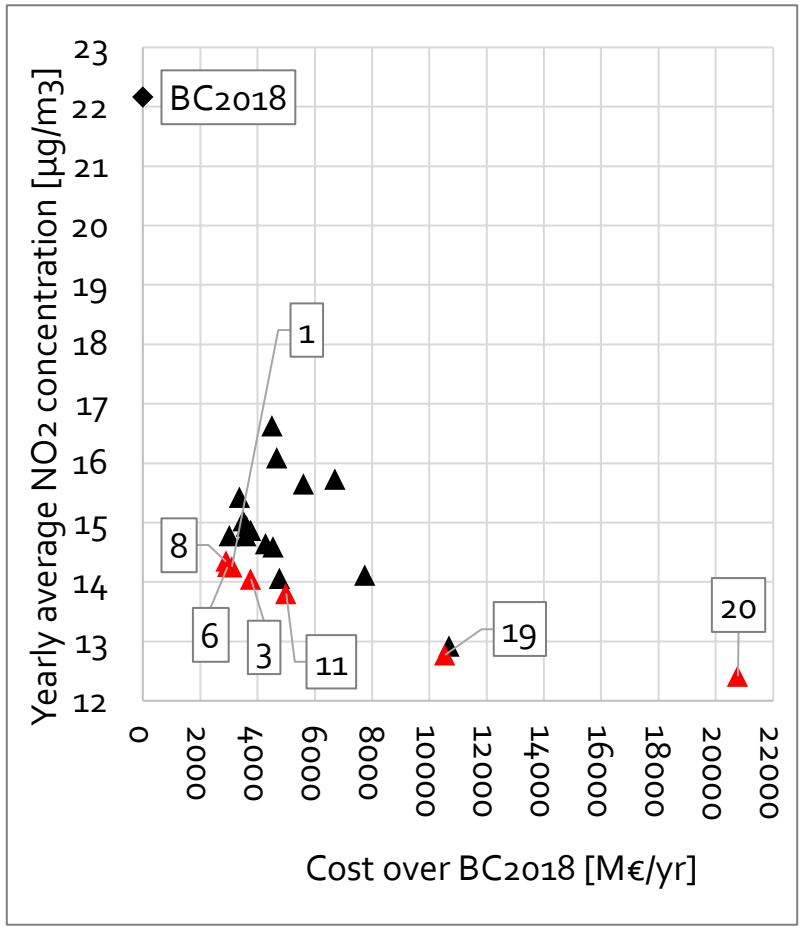
Problem solutions

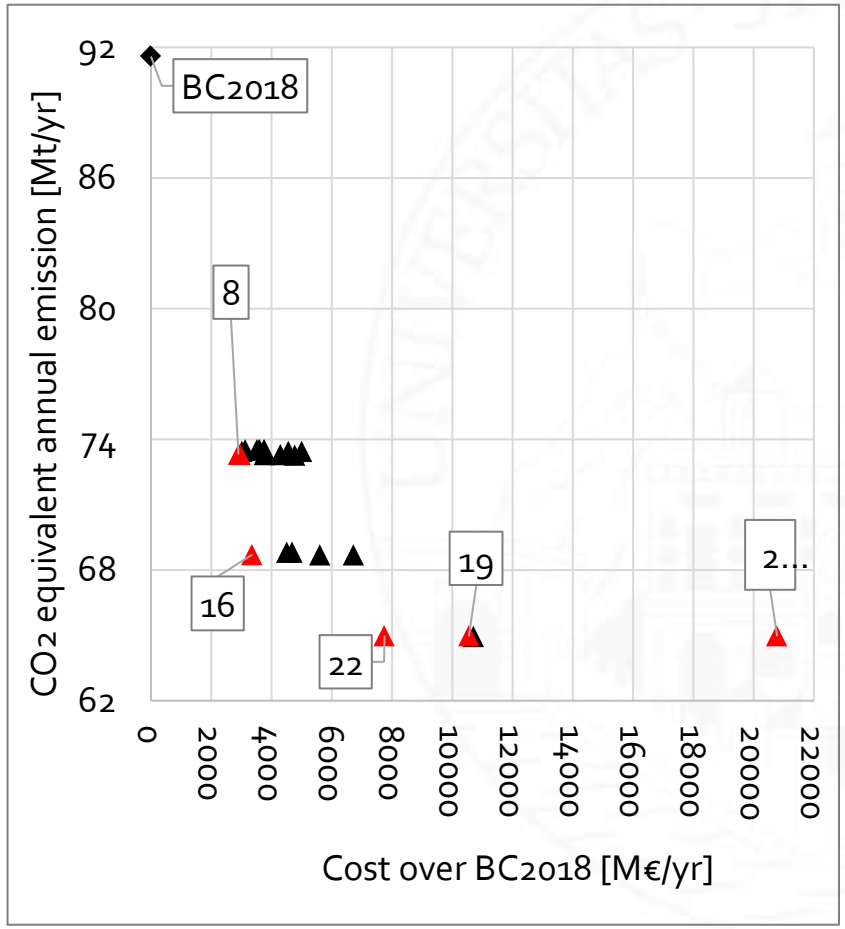
$PM_{2.5}$



NO_2



CO_2 eq



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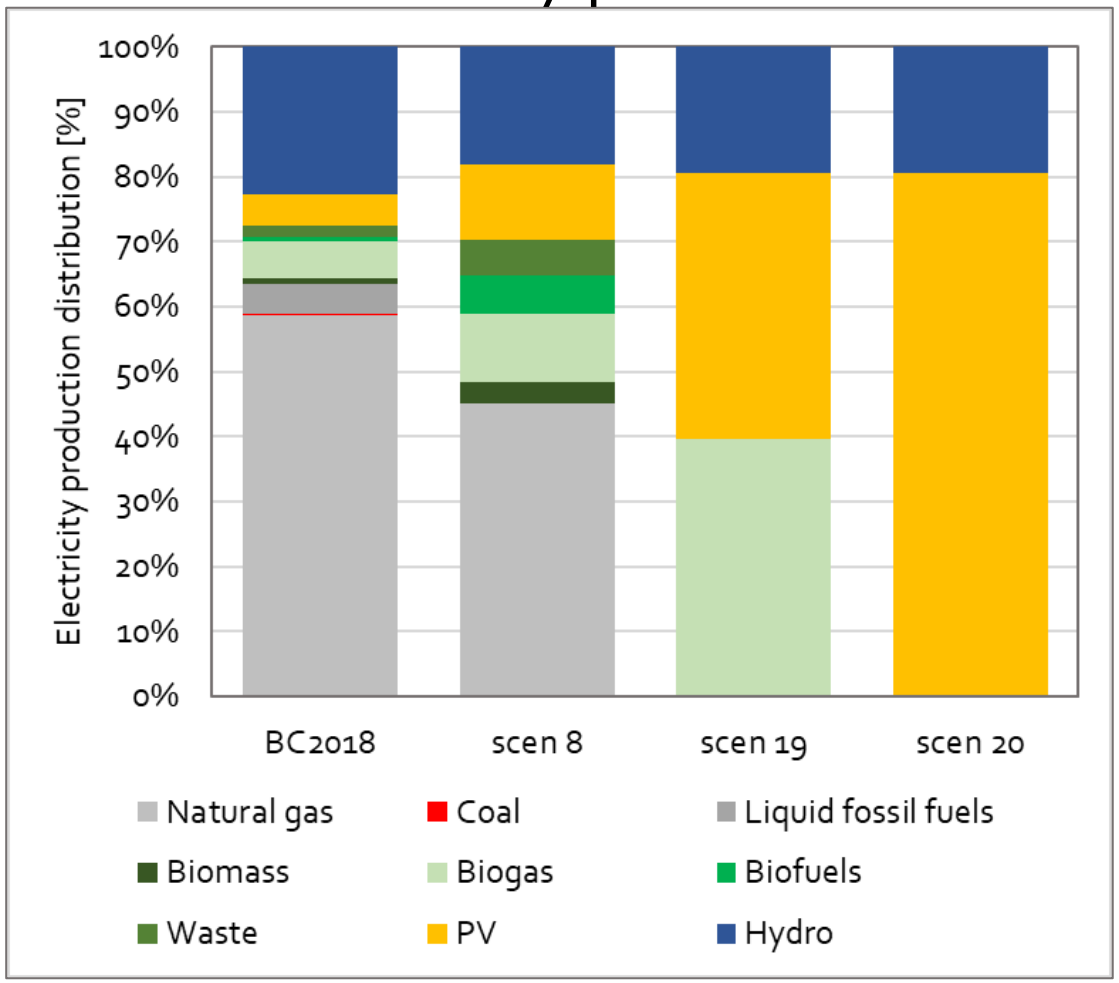
Problem solutions are the not dominated scenarios in all objective spaces:

scenarios 8, 19 and 20

Problem solutions

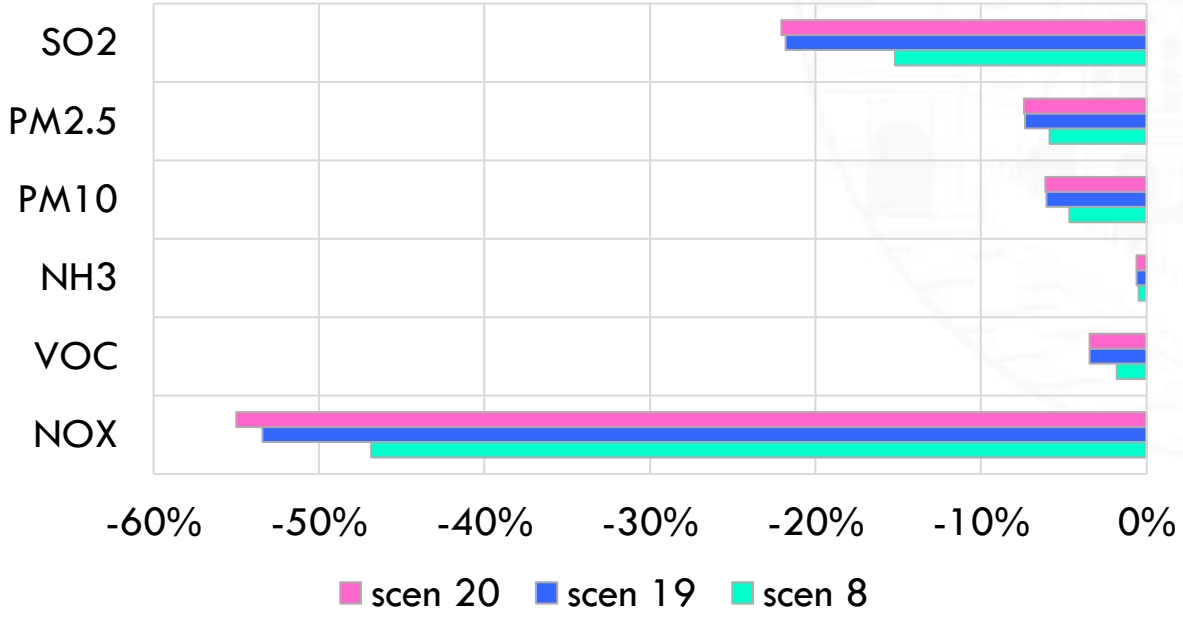
Electricity production



Objectives

Scen	Cost over BC [M€/yr]	$\Delta PM_{2.5}$ [%]	ΔNO_2 [%]	ΔCO_2 eq [%]
8	2905	-5.1%	-35.3%	-20.0%
19	10550	-6.1%	-42.4%	-29.1%
20	20773	-6.2%	-44.0%	-29.1%

Percentage emission reduction



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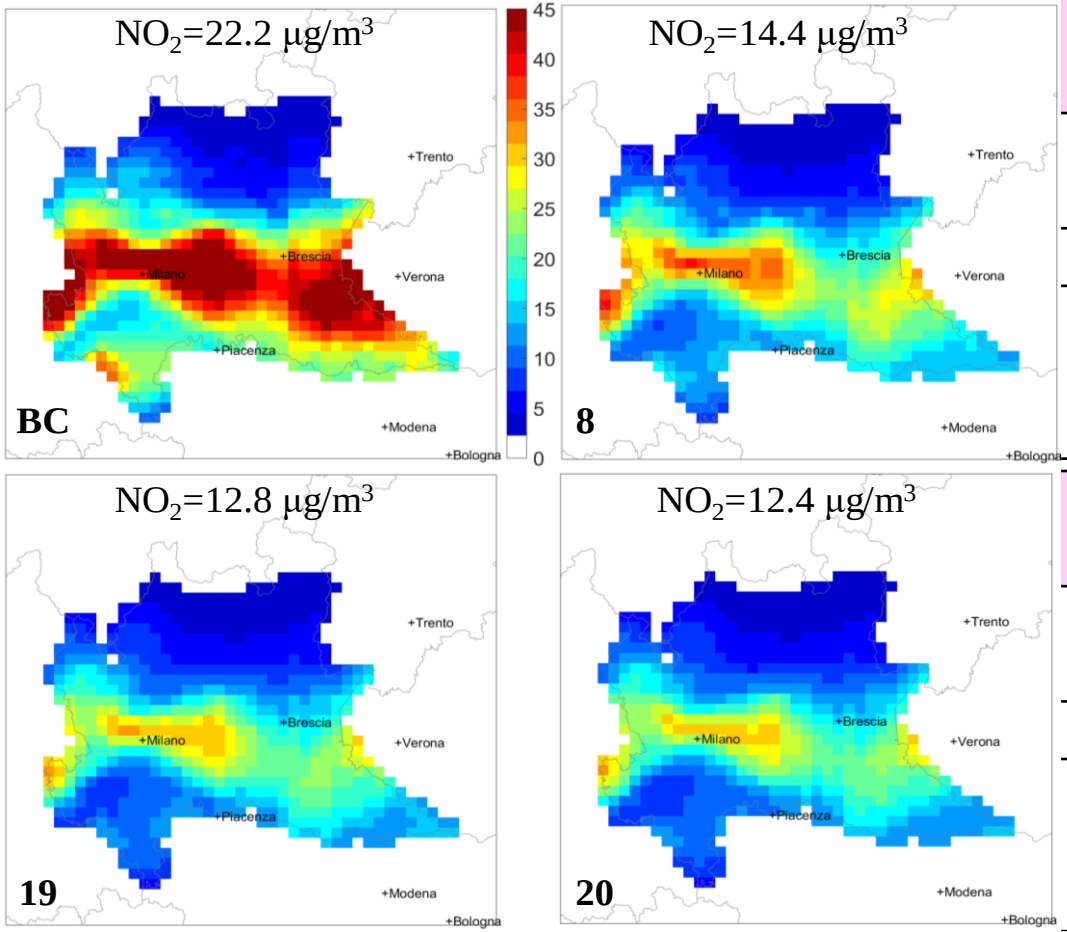
Problem solutions: health impact assessment



	Cost over BC	Mortality YLL			
		PM2.5		NO2	
	M€/yr	Months/ person	%	Months/ person	%
BC2018	0	9.9	-	1.3	-
8	2905	9.5	-4.8%	0.86	-35%
19	10550	9.4	-5.8%	0.76	-42%
20	20773	9.4	-5.8%	0.74	-44%

	Cost over BC	YLL costs			
		PM2.5		NO2	
	M€/yr	M€/yr	Δ M€/yr	M€/yr	Δ M€/yr
BC2018	0	4926	-	955	-
8	2905	4659	-267	649	-306
19	10550	4592	-334	570	-385
20	20773	4583	-343	554	-401

	Cost over BC	Energy savings
scen	M€/yr	M€/yr
8	2905	3229
19	10550	4275
20	20773	5874

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Thank you for your attention

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This study is founded by:

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