IEEP

Environment Center
Charles University
in Prague

Economic and Environmental Impacts Assessed by Econometric Model E3ME

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Conference on "Assessing The Impacts Of Environmental Regulation By Macroeconomic Models", Prague 23-24 November 2009

Outline

I. E3ME model
- Main features
- Effects of Taxation

II. Extensions and updates of the Czech module

III. Policy scenario assessment
- Effects of the Czech MoE proposal on emission charging
- Ancillary effects of carbon taxation and airborne pollutant charging

The E3ME Model

E3ME Model

An Energy-Environment-Economy Model of Europe

- Built by a European team under the EU JOULE/THERMIE program as a framework for assessing **energy-environment-economy issues and policies**; further developed by Cambridge Econometrics & 4CMR (E3MG)
- **Forecasting and scenario analysis**, across a range of GHG mitigation policies in Europe, including C tax and permit trading
- E3ME provides an econometric one-model approach in which the detailed industry analysis is consistent with the macro analysis
  - industrial factors influence the macro-economic picture by full **macro top-down** and **industrial bottom-up** simulation analysis
  - supplemented by a set of **bottom-up engineering submodels**, i.e. detailed treatment of electricity supply industry

Common features of IDIOM

[International Dynamic Input-Output Modelling]

Structural

- disaggregation of variables (sectors, fuels, commodities)

Organized around a **Social Accounting Matrix**

- i.e. on accounting principles, e.g. System of National Accounts

Dynamic

- **behavioural equations** with effects from previous outcomes
- illustrating the response of the main economic indicators to standard changes in the assumptions

Estimated on cross-section & time-series data

- identifies **current-year responses** and **long-term trends** (cointegration)
- allows sectoral and regional differences

Forward-looking

- an in-depth treatment of **changes in the input-output structure** of the economy over the forecast period to incorporate the effects of t**echnological change**, **relative price movements** and **changes in the composition** of each industry's output
- projections annually

E3ME

- varying competition over sectors
- varying returns to scale
- product supply-demand balance
- unemployment
- projection based on long TS data used for econometric estimation

‘usual’ CGE

- perfect competition
- constant returns to scale
- equilibrium solution
- full employment
- projection based on one year's data
- guess-estimated parameters

E3ME

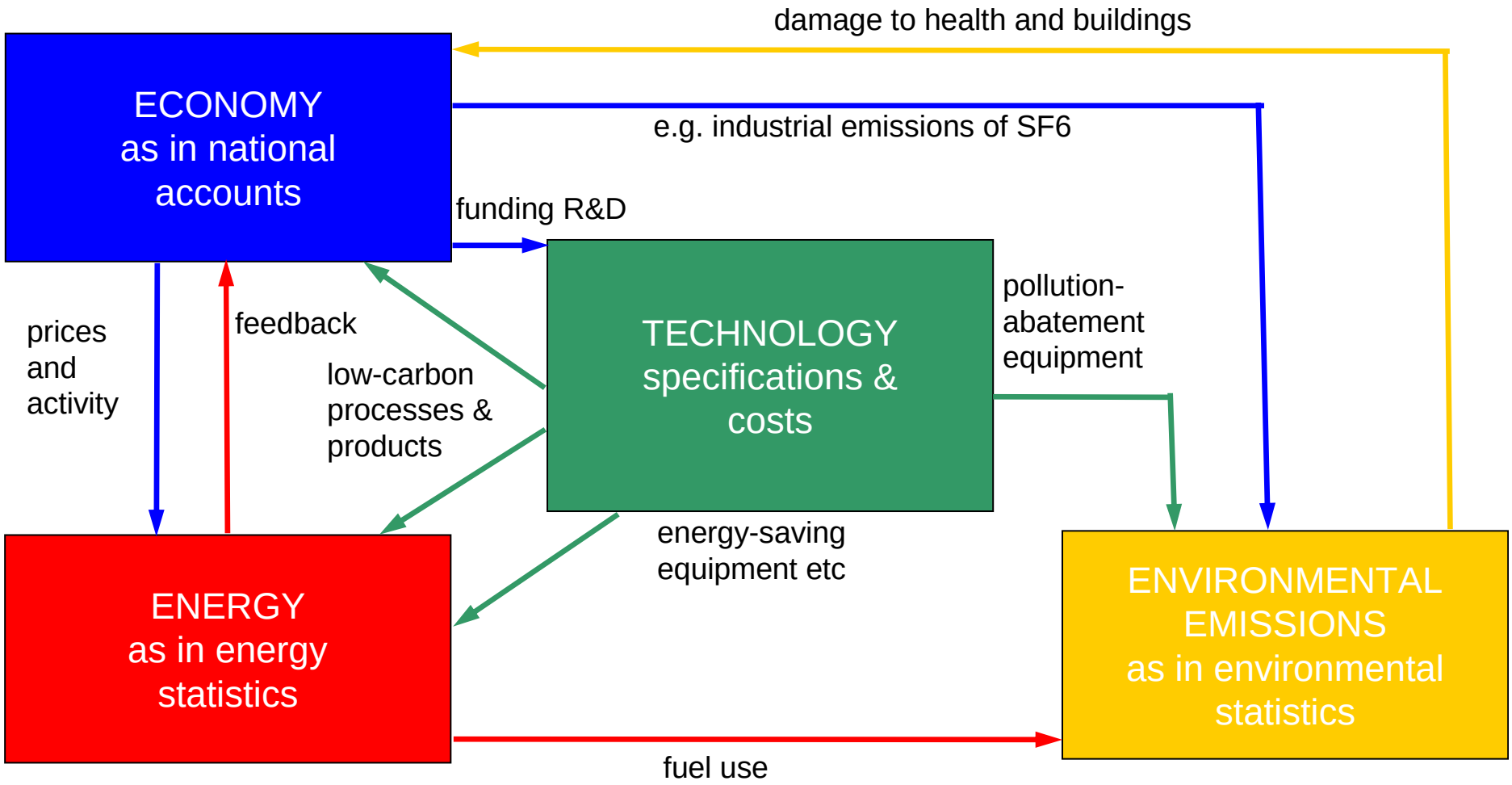
Exog variables

Population
Natural resources (coal, oil, gas)
Current and capital spending of government
Tax rates and allowances
Exchange rates
Short- and long-term interest rates
World prices of traded goods, e.g. crude oil
Rest-of-world GDP and inflation

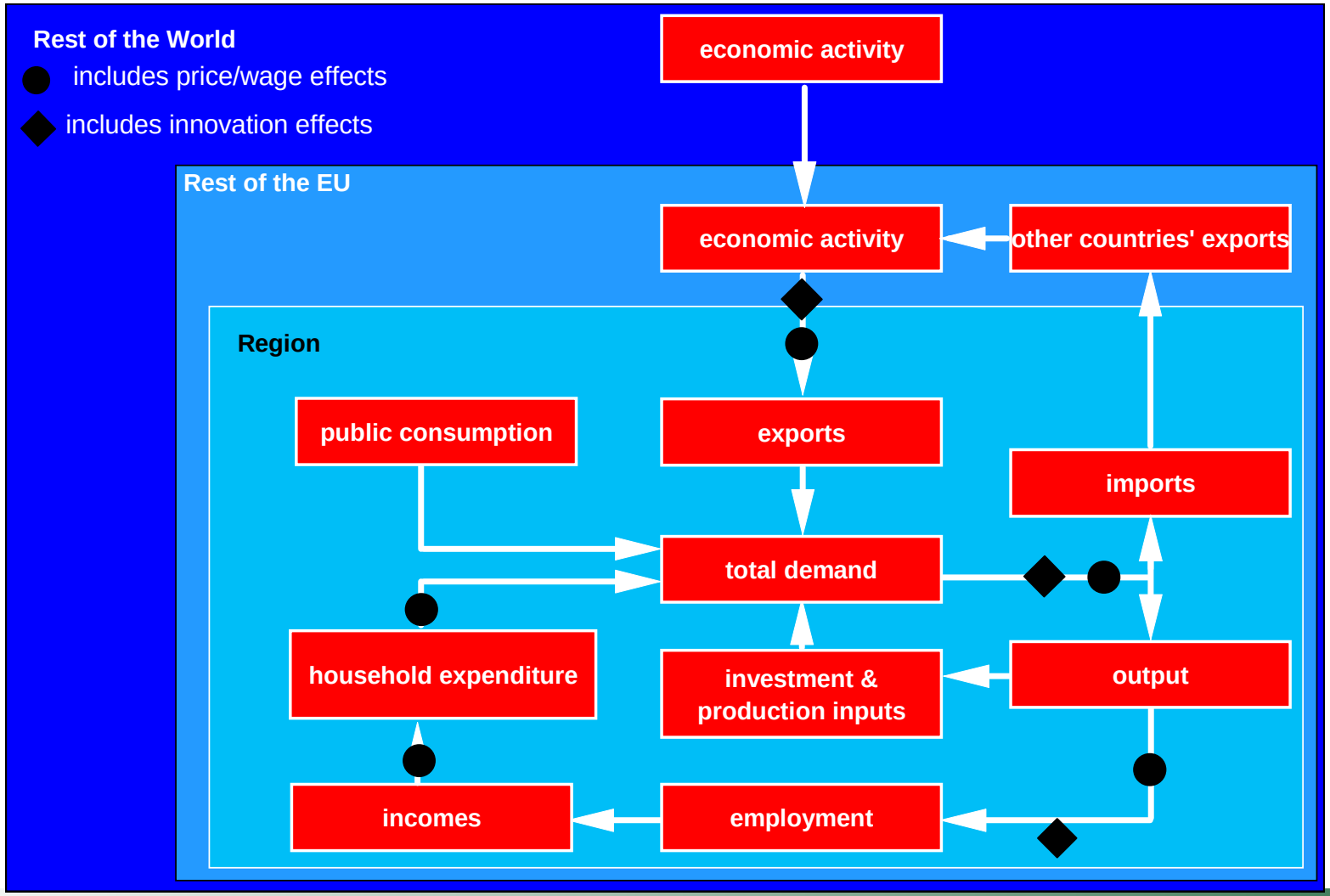
Stochastic eq. sets

Aggregate energy
Shares of coal, oil, gas and electricity
Aggregate and shares of hh consumption
Industrial investment
Exports and imports
Hours worked
Industrial employment
Industrial prices
Export and import prices
Industrial average earnings
Labor market participation rate
Residual income (non-employment)
Investment in dwellings
Output

E3ME: The Main Links



E3ME: The Determination of Output



Taken from Pollitt & Chewpreecha 2008

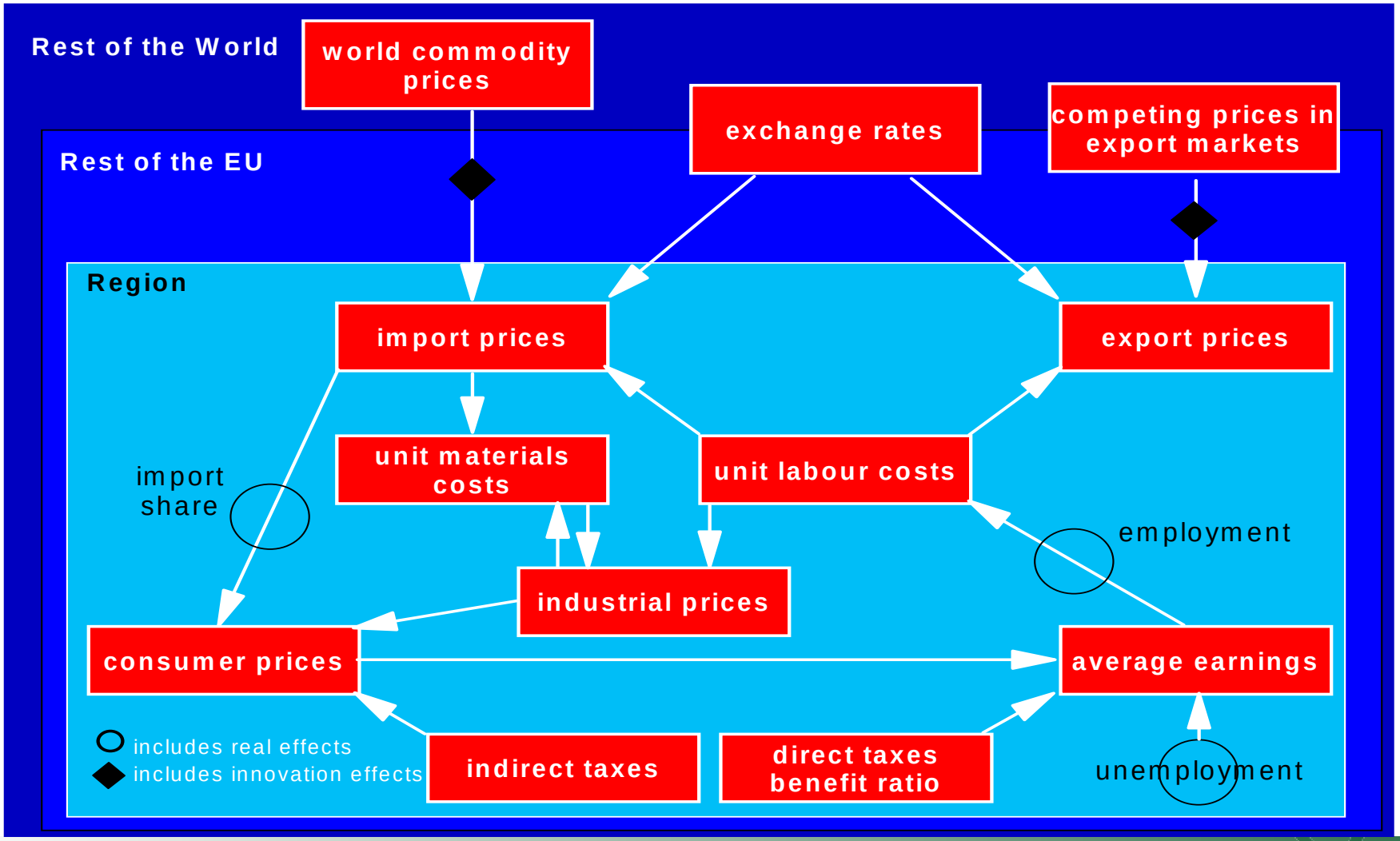
E3ME: Modelling of International Trade

- International trade: relevant region vs. EU transport and distribution network
- Trade volumes divided between trade internal to the single market and external trade
- A key explanatory variable is the indicator of export market activity (derived by weighting together activities in export markets by trade shares taken from bilateral trade matrices)
- All trade affected by relative prices

E3ME: Modelling Consumption

- Aggregate Consumption is dependent on real gross disposable income, household wealth, real interest rate, dependency ratios.
- In the case of the error correction equation, the changes in the unemployment rate of the country.
- Consumption is further disaggregated in 42 goods/sectors that cover all types of consumer goods and services.

E3ME: The determination of prices



Taken from Pollitt & Chewpreecha 2008

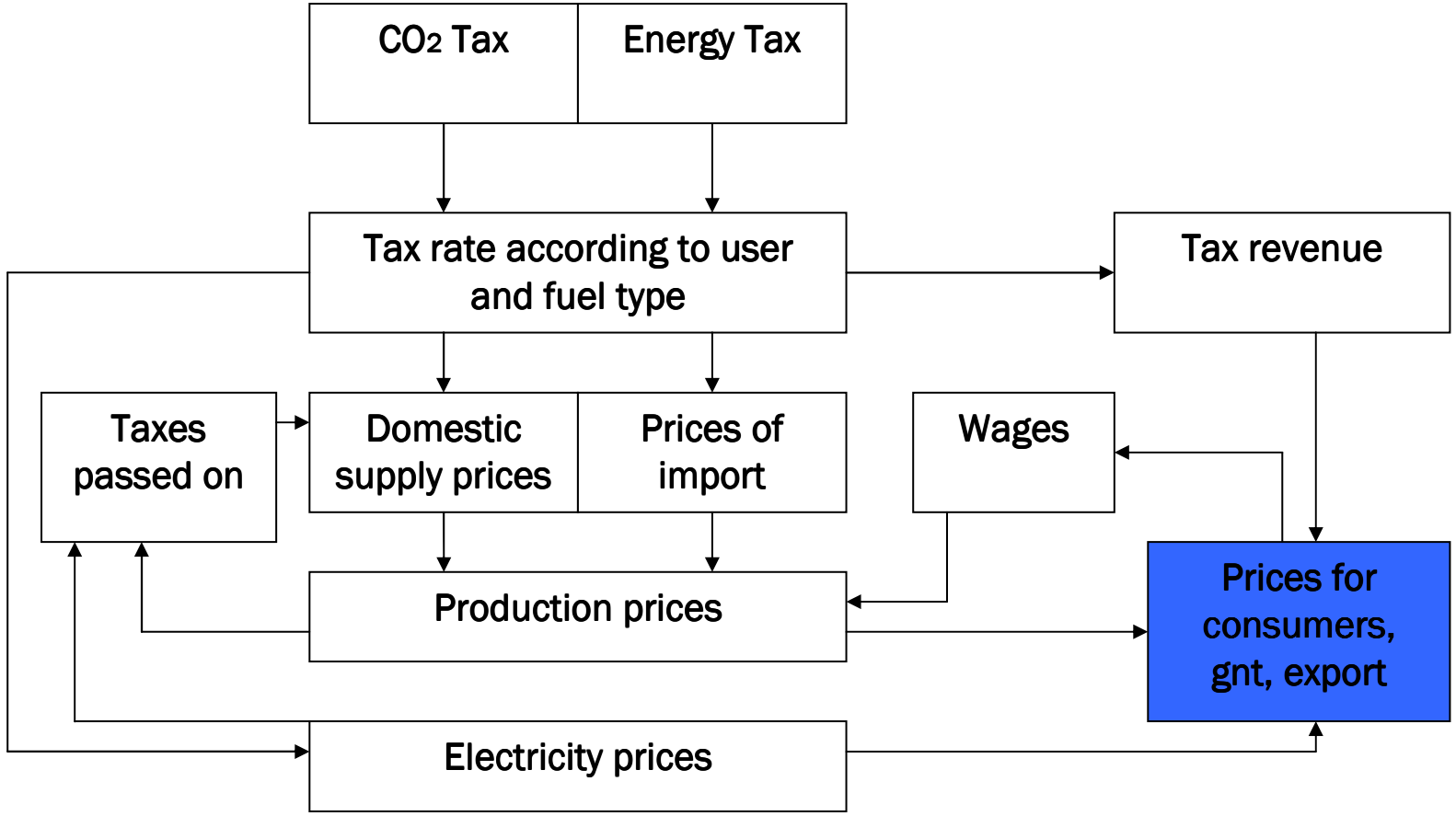
E3ME: Modelling of Energy Demand

- 2-level hierarchy:
  - aggregate energy demand equations and
  - fuel share equations
- Aggregate demand is affected by level of economic activity of inspected sector, price of energy products, investments, R&D
- Fuel share equations: estimated for 4 main fuels, again the variable depend on total energy demand, price of energy carrier, investments and R&D in the sector

E3ME: Impacts of Energy Tax

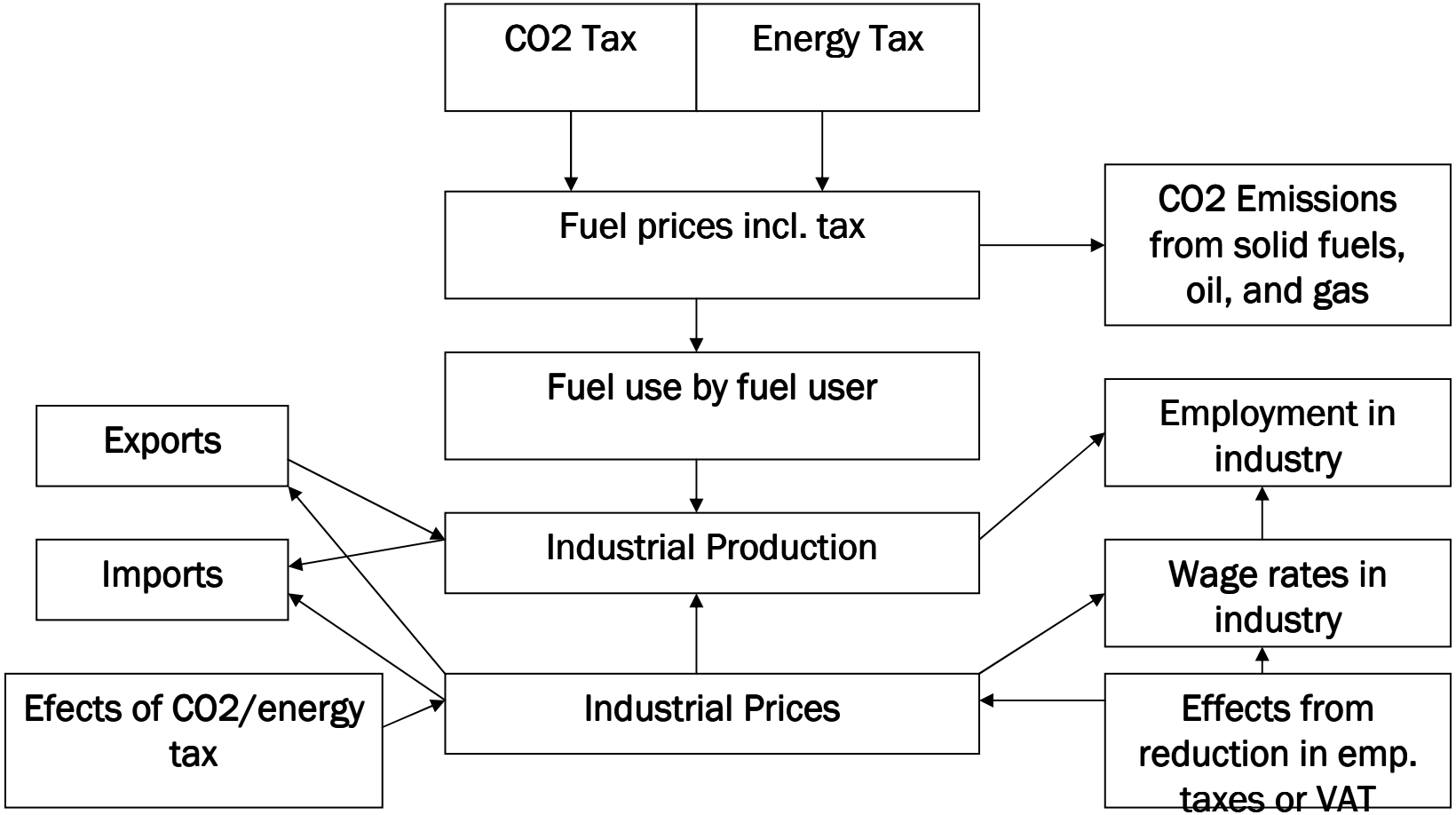
- CO2 or energy content subject to taxation
- Domestic consumption and imports subject to taxation, export excluded
- Fuel users passed on higher costs on their production
- Relative consumption of goods with carbon/energy content affected
- Higher consumer prices lead to higher wage claims

E3ME: Impacts of Energy Tax (on wage rates, prices)



Source: www.e3me.com

E3ME: Impacts of Energy Tax (on fuel use)



Source: www.e3me.com

E3ME: The ETS

The ETS is fairly stylised:

- Allowances are treated as taxes on energy use, depending on the carbon content of fuels
- Increases in costs are passed on to consumers
- Prices may be entered exogenously or calculated by the model – however, market clearing is assumed
- Allocated allowances are used to increase profits
- No links to areas outside the EU or JI/CDM schemes
- No awareness or signalling effects
- No feedback to energy prices, which are exogenous
- Possible to choose among grandfathering, auctioning

Application: Inspected Scenarios

- Idea: Choose 2 scenarios with equal cumulative savings in external costs, analyze results, particularly focus on ancillary effects (co-effects)
- The first scenario includes only taxation of SO2, NOx, PM, and VOC
- The second scenario is based on additional consumption tax (imposed on carbon content of the fuels)
- The development of the rates has the same pattern (weighting of the emissions from BAU scenario)
- Trial-error method
- Two main scenarios are compared, third scenario provided for better understanding of impacts
- Assumption of existence of the ETS with exogeneous permit price as given by the PRIMES model

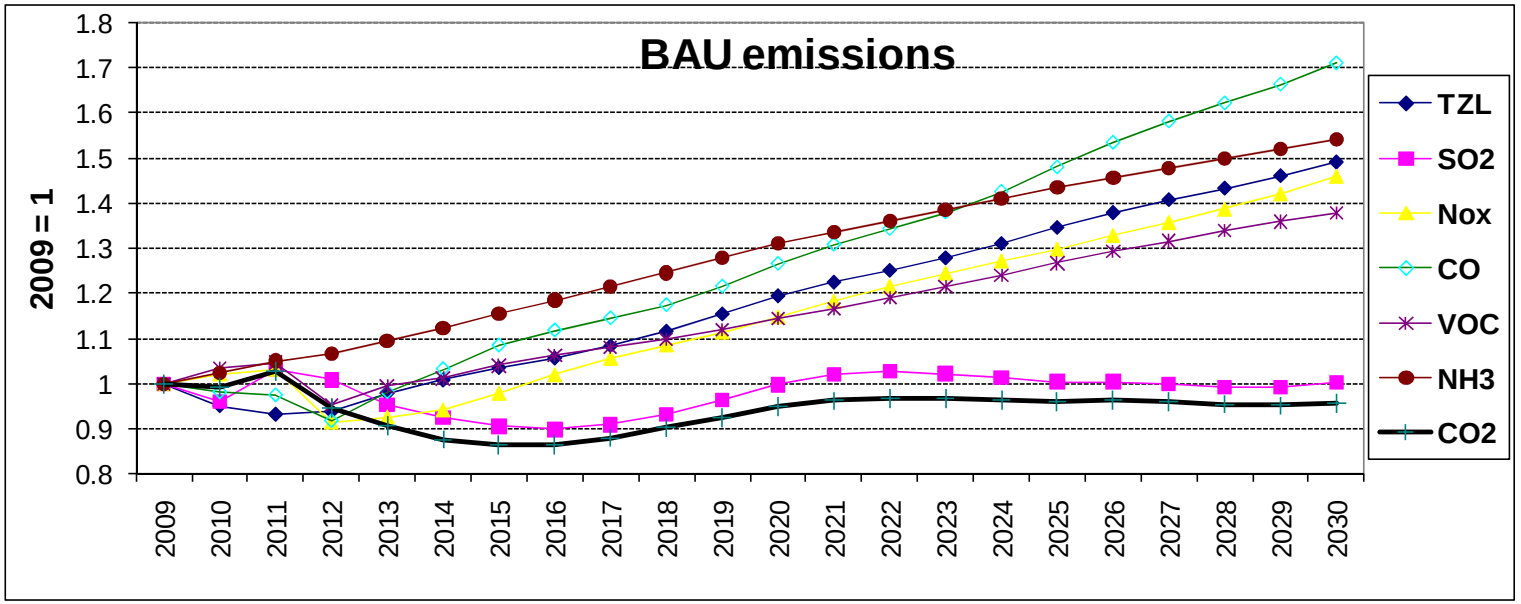
Extensions and updates of the Czech module of the E3ME model

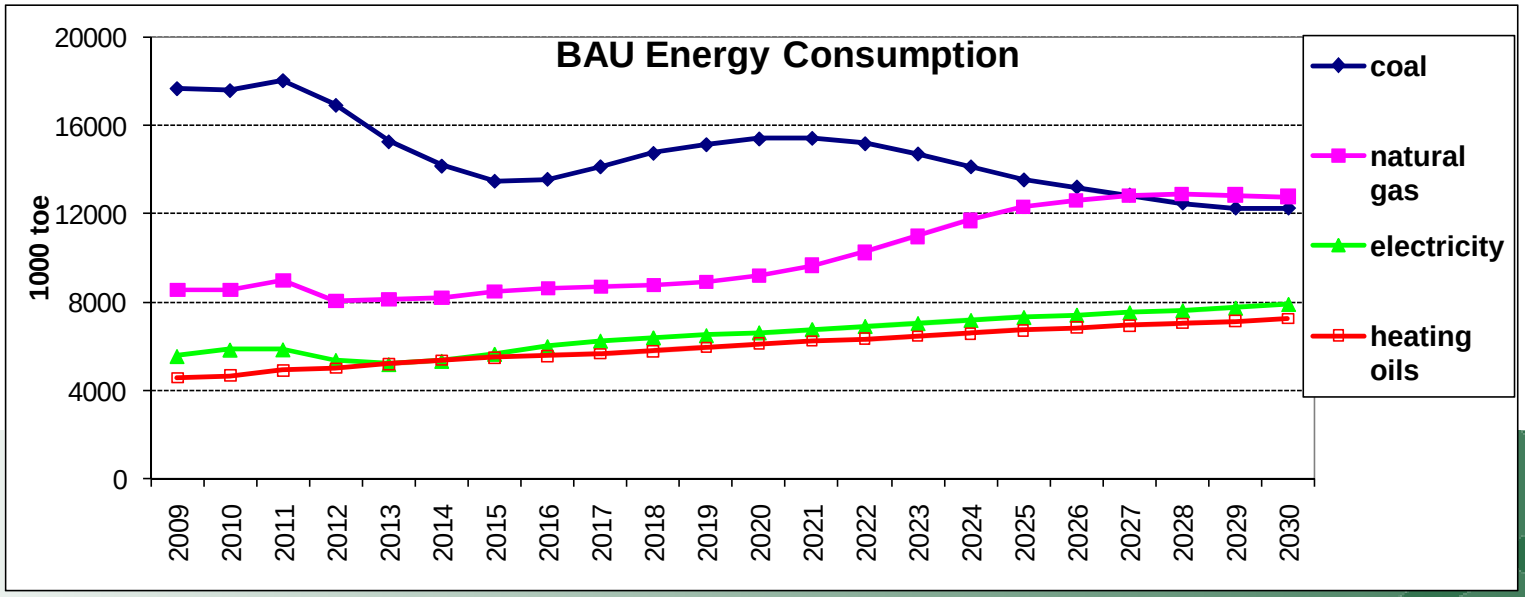
The E3ME of the Czech Economy

The Czech economy as a part of Pan-European model, but extensively updated and extended within MODEDR project

- 2005 input-output table and SAM
- emission of SO_2, NOx, PM, CO, NH_3 and VOC suppl. to GHG's
  - detailed breakdown by 19 energy users and 5 fuel sources
  - emission coefficients are assumed fix throughout forecast years
- forecast period extended from 2020 → 2030
- revised assumption set for the baseline that
  - ✓ assumptions based on historical data by 2005
  - ✓ updates assumptions by historical econ data by 2008 and parameters re-estimated, incl. updates of exchange rates and oil prices etc.
  - ✓ considers also the effects of financial crisis and policy responses of the government based on global E3MG (Barker, Pollitt 2009)

E3ME 2009> The Czech BAU forecast {3a}





E3ME policy scenarios

Allows to predict effects for various policy scenarios which **affects the fuel price** of fuel users or sectors

- Energy tax *[€/toe] including exemptions by fuel user or fuel type*
- Carbon tax *[€/tC]*
- CO_2 allowance price *[€/tC]* --- default exogenously by PRIMES forecast
- *CO_2 & GHG target reduction below 1990*
- *Share of grandfathered allocation of CO2 allowance*
- *CO_2 emission permit allocation for each ETS phase [tC per fuel user]*
- *Emission charge on SO_2, NOx, PM, CO, NH_3, VOC [€/t per fuel user!]*

Including a **revenue recycling** through

- *labor tax cuts (incl. SSC paid by employees or employers), or*
- reducing direct/indirect tax burden

Sensitivity analysis

- on exogenous variables, e.g. world oil price, exchange rates etc.

Application 1

The effects of emission charging

E3ME Applications for the Czech Republic

- Czech MoE 2009 proposals to increase emission charge rates
  - May 2009
    - 20-40 times increase in the rates of SO_2, NOx, PM and VOC to reach MAC as derived by GEM-E3 model for CZE (Van Regemorter 2008)
  - August & November 2009
    - Scenario 1: 10x larger rates for SO_2, NOx, PM, VOCs over 2010-2021
    - Scenario 2: 40% increase in the rates of SO_2, NOx, PM, VOCs in 2010
    - Scenario 3: Abolish the charges on 6 pollutants in 2010

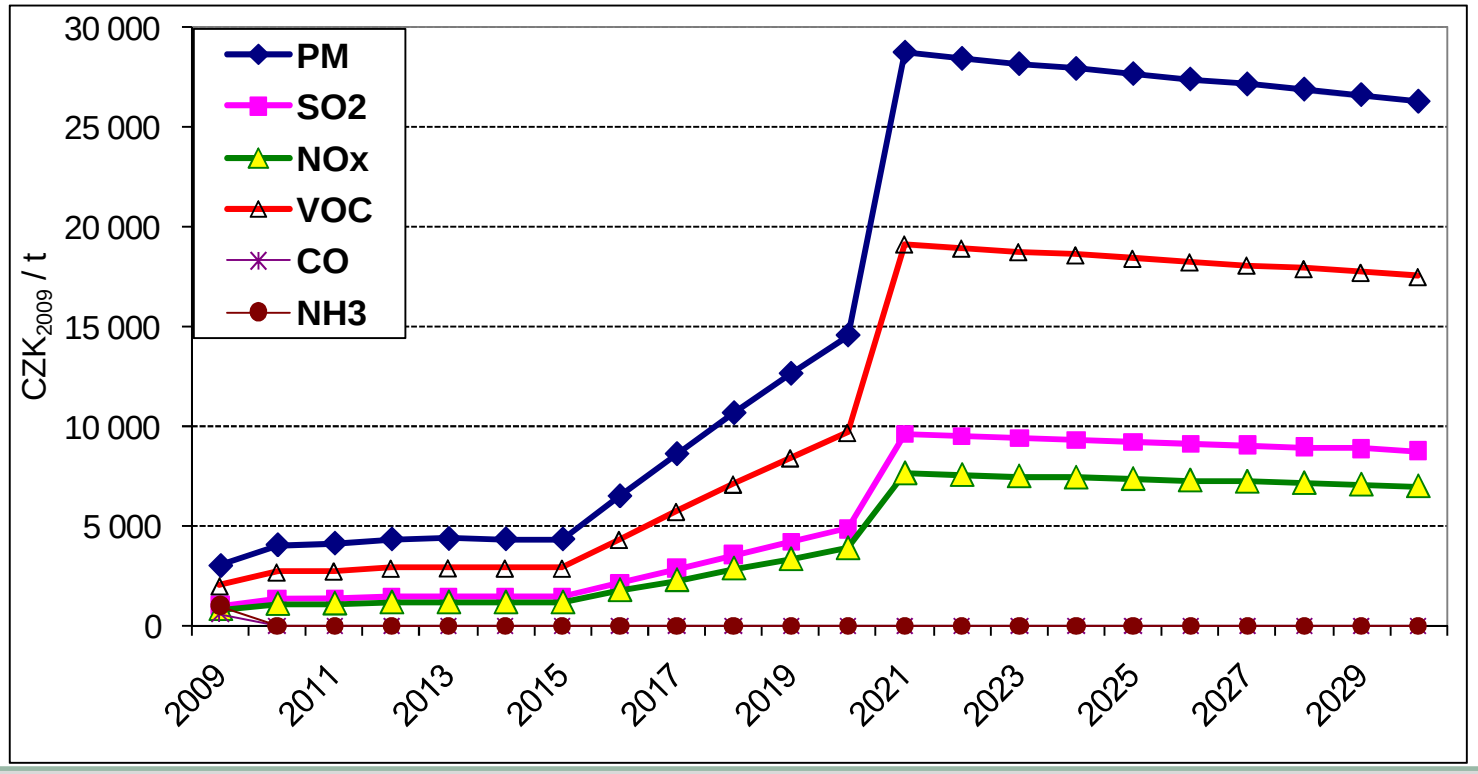
- Carbon or pollutant abating policies → looking at ancillary effects

  Ščasný, M., Píša, V., Pollitt, H., Chewpreecha, U., (2009), Analysing Macroeconomic Effects of Energy Taxation by Econometric E3ME Model. *Czech Journal of Economics and Finance, 5/2009* (forthcoming) --- presented on Tuesday

- CO_2 allowance price

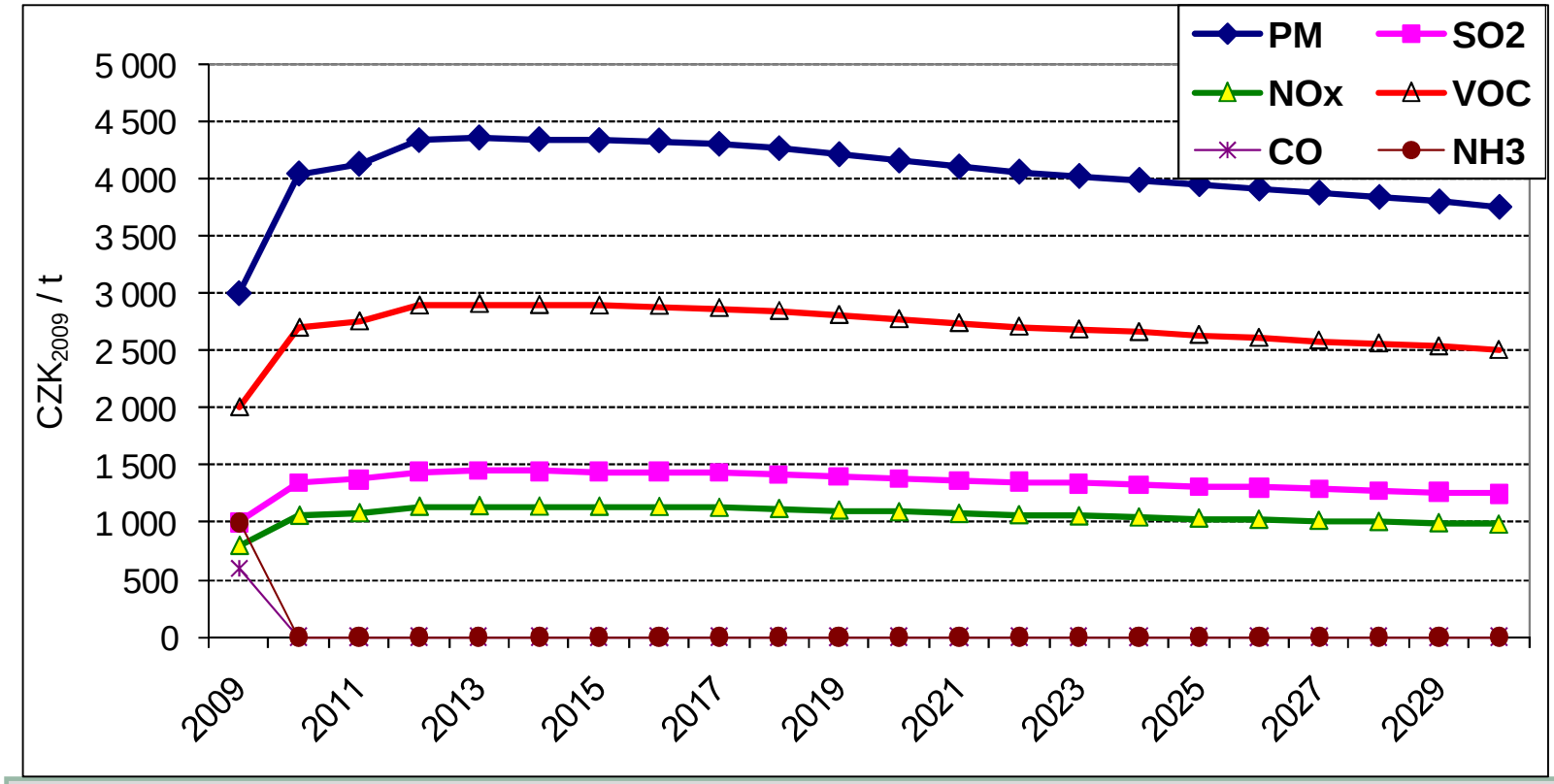
  exogenous price as derive by PRIMES model (DG TREN 2008) in all scenarios

Main policy> Scenario 1



- EU ETS allowances with exogenous price
- assumptions with financial crisis and policy responses
- with and w/o the revenue recycling
- only stationary sources and fuel users are subject of charging
  - 81% of SO_2 and 73% of NOx
  - but only 22% PM and 20% VOCs (2% NH3)

Main policy> Scenario 2



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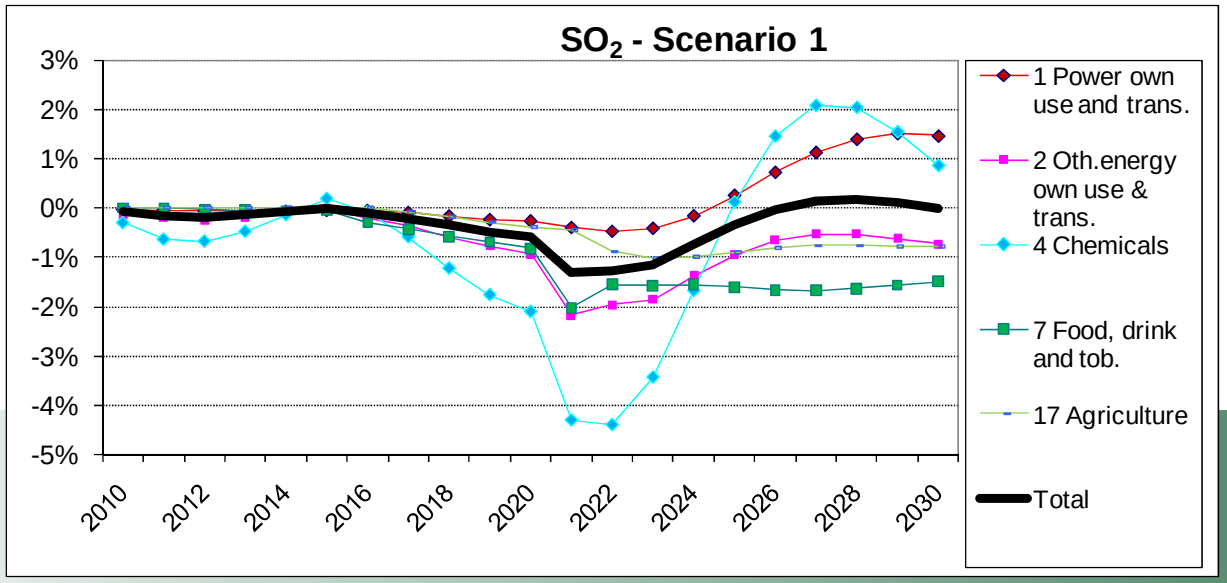
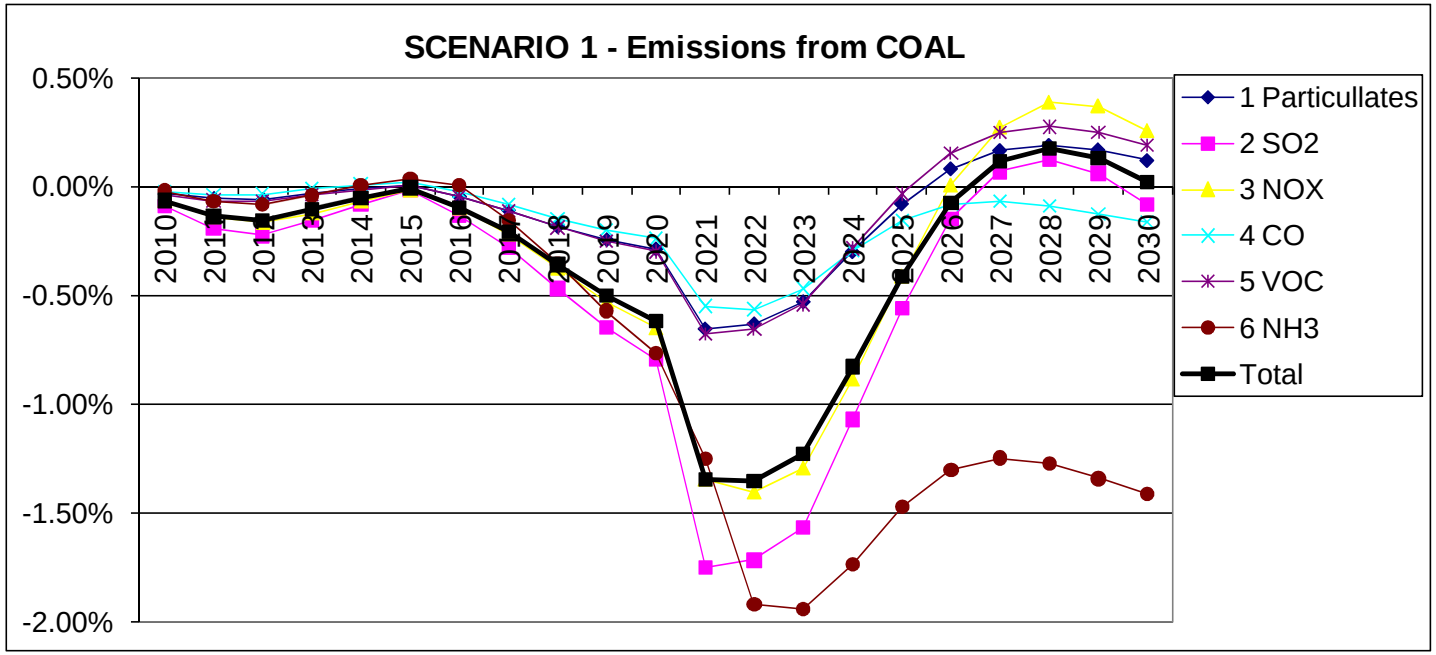
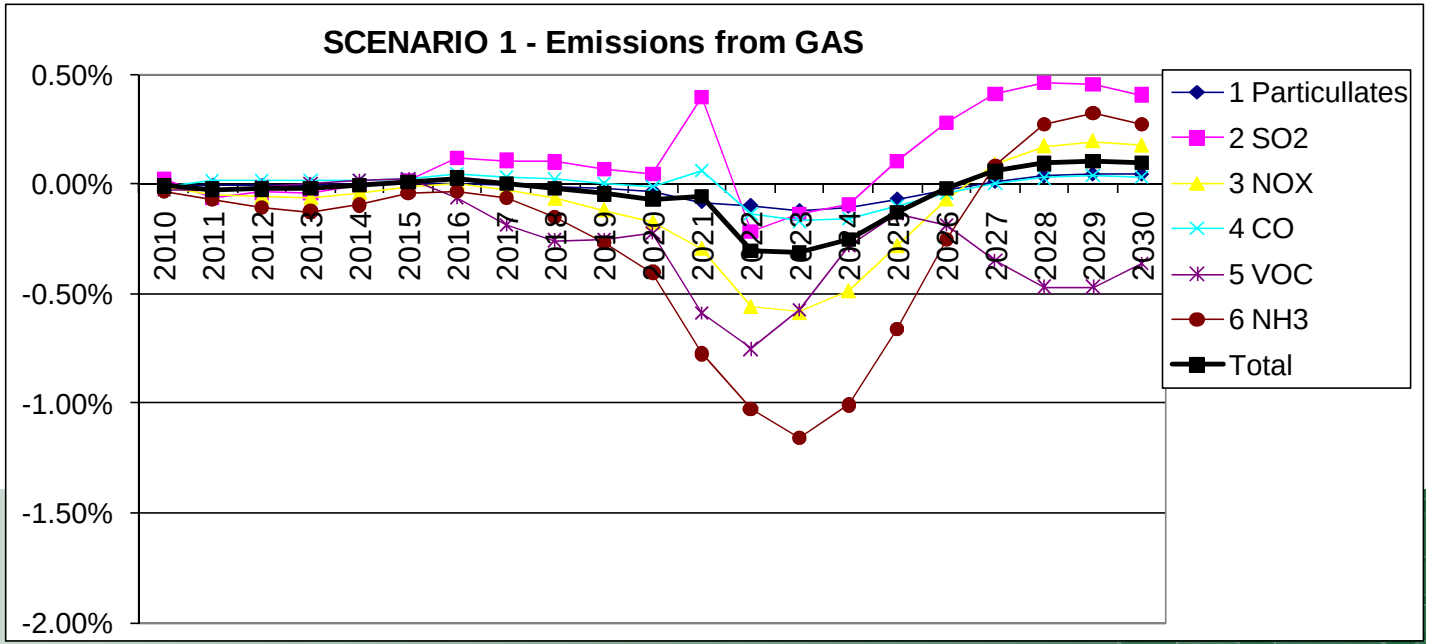
Emissions

- Very small reductions compared to BAU [up to units of %] even in Scenario 1; overall effect and in long-run would be negligible
- The effects on sectors vary; in power, emissions are increasing after its production process adjusts to the price changes
- The largest changes in SO_2 and NOx, but still very small; negligible effects in other pollutants
- CO_2 reduced by 0.4% to 0.7% over 2021-2025
- Abolishment of six charges would slightly increase respective emissions [up to 2% in some sectors]; overall the effect is negligible

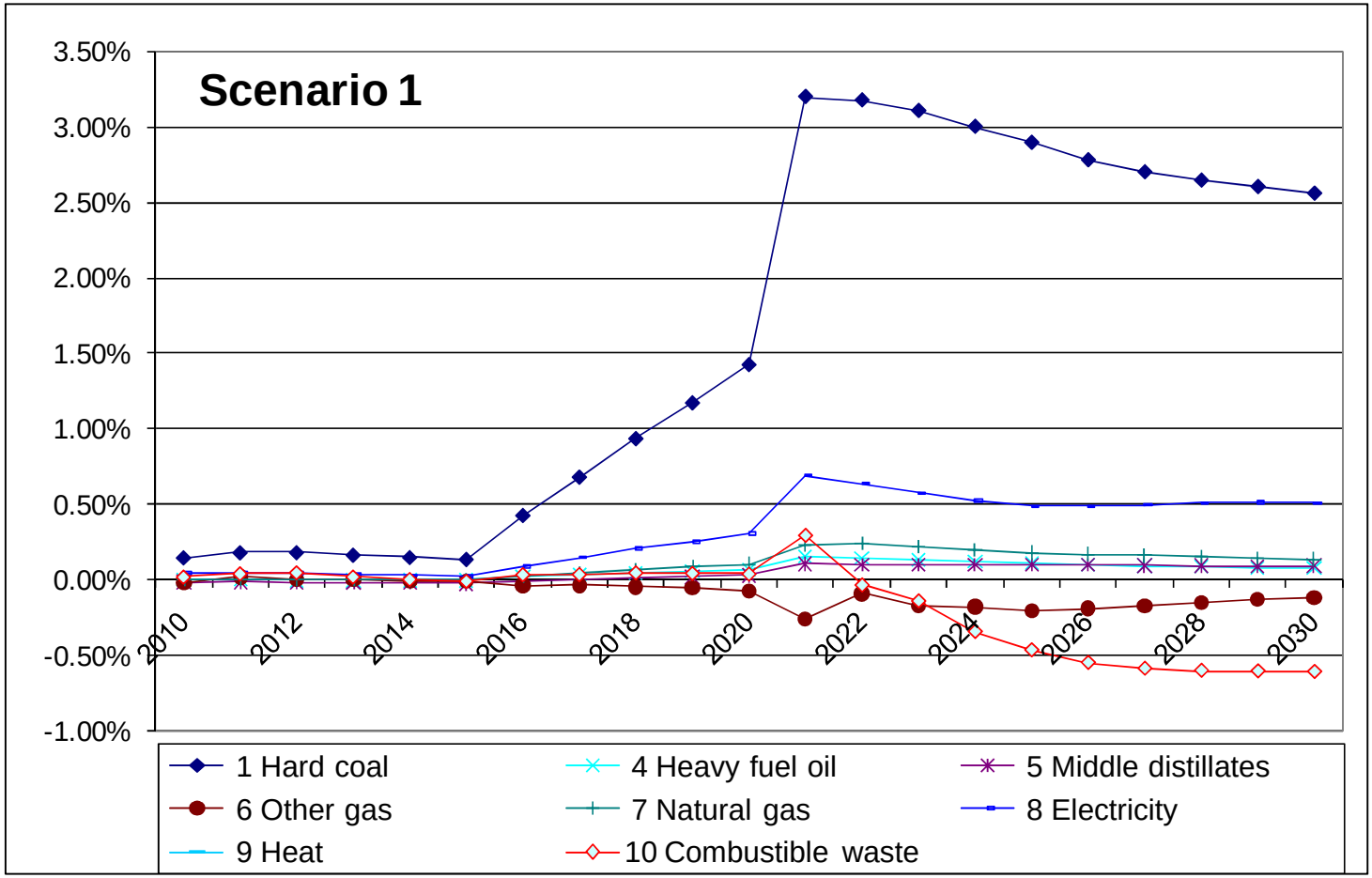


Emission

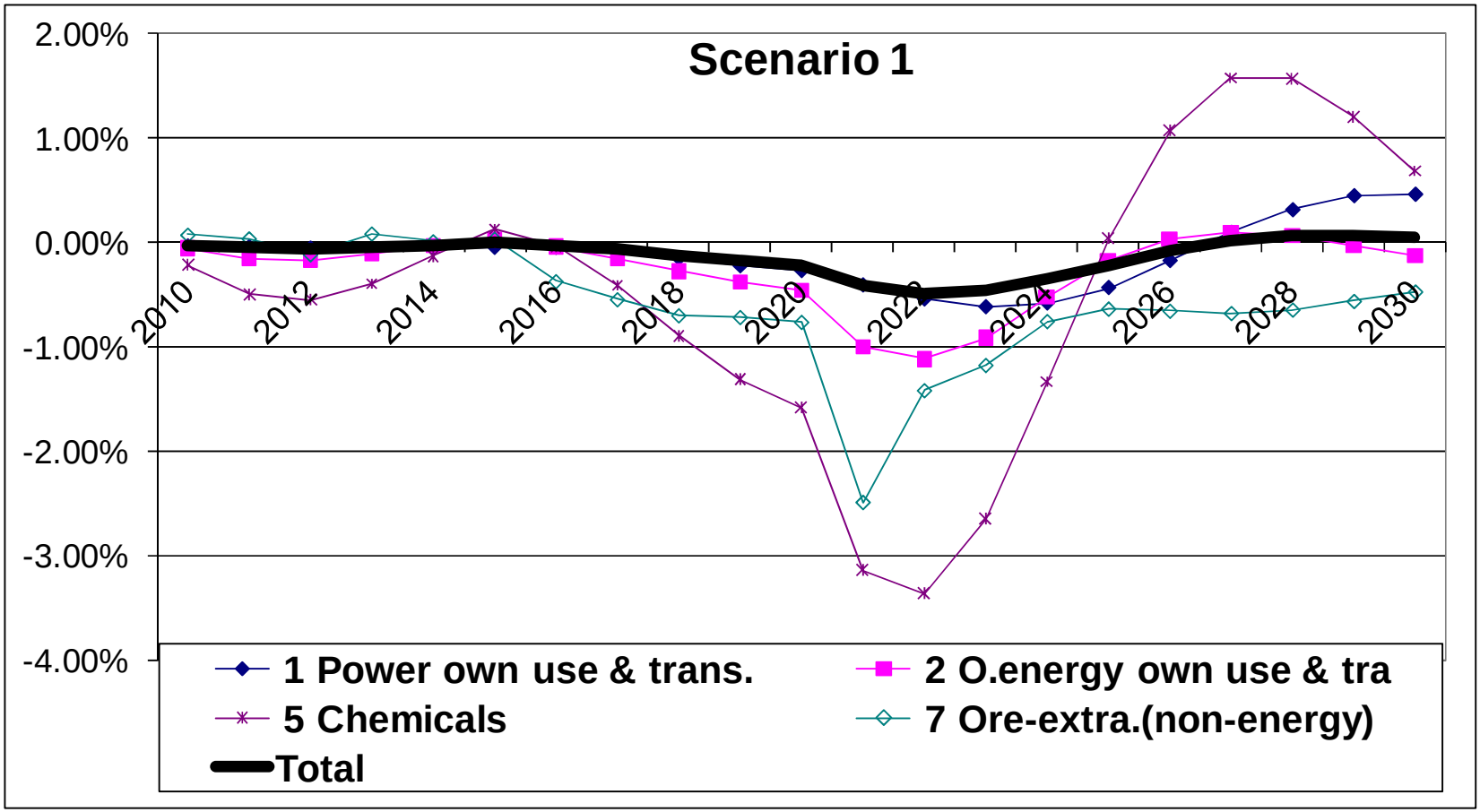

SCENARIO 1 - Emissions from COAL
0.50%
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
1 Particullates
2 SO2
3 NOX
4 CO
5 VOC
6 NH3
Total


SCENARIO 1 - Emissions from GAS
0.50%
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
1 Particullates
2 SO2
3 NOX
4 CO
5 VOC
6 NH3
Total

Fuel prices


Scenario 1
3.50%
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
-0.50%
-1.00%
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
1 Hard coal
4 Heavy fuel oil
5 Middle distillates
6 Other gas
7 Natural gas
8 Electricity
9 Heat
10 Combustible waste

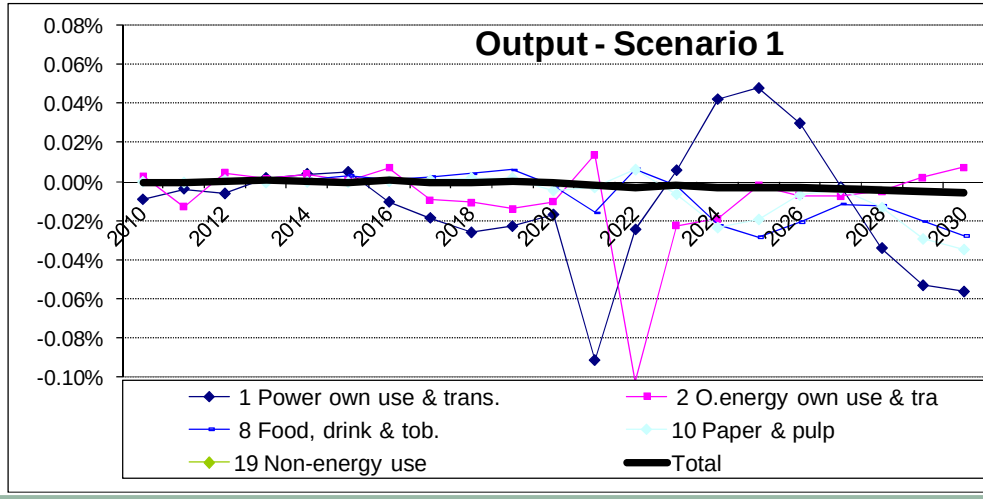
Energy consumption



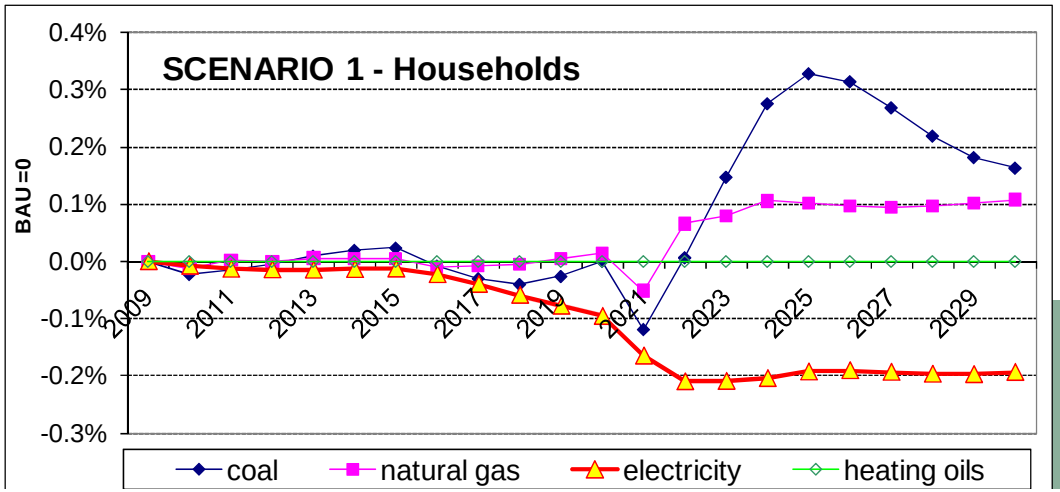
Additional revenues and avoided externalities *[in bln. CZK p.a. & in total]*

	2010-2015	2015-2020	2021-2025	2025-2030	Total 2010-2030
Scenario 1					
revenues	0.029	1.058	4.550	4.785	**52.137**
externalities	-0.107	-0.419	-1.406	-0.229	**-10.913**
Scenario 2					
revenues	0.029	0.000	-0.010	-0.040	**-0.075**
externalities	-0.107	0.033	-0.065	-0.025	**-0.923**
Scenario 3					
revenues	-0.624	-0.684	-0.778	-0.843	**-15.267**
externalities	0.395	-0.019	0.224	-0.019	**3.295**

Economy

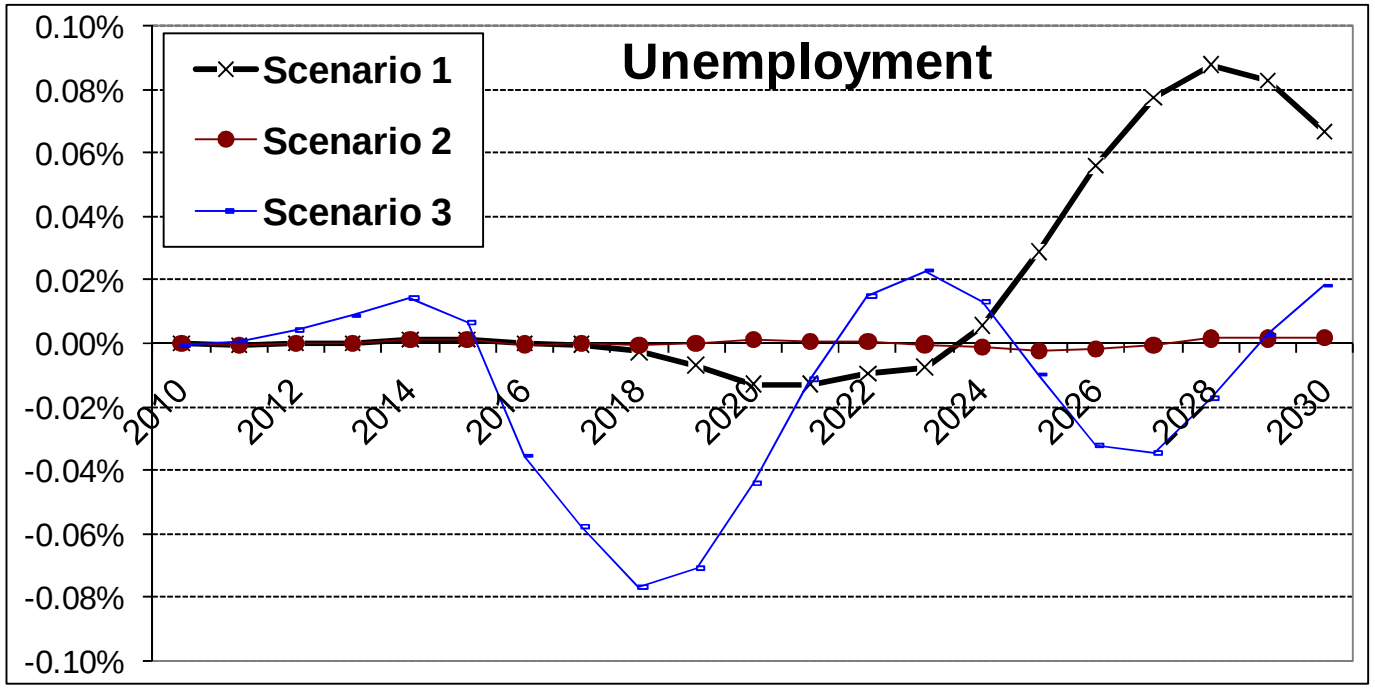


- very small effect on **output, GDP and industry value added** [up to -0.01% of BAU]
- even smaller negative effect on **consumption and investment**
- the highest rates involve **import increases**, but the effect is absolutely very small



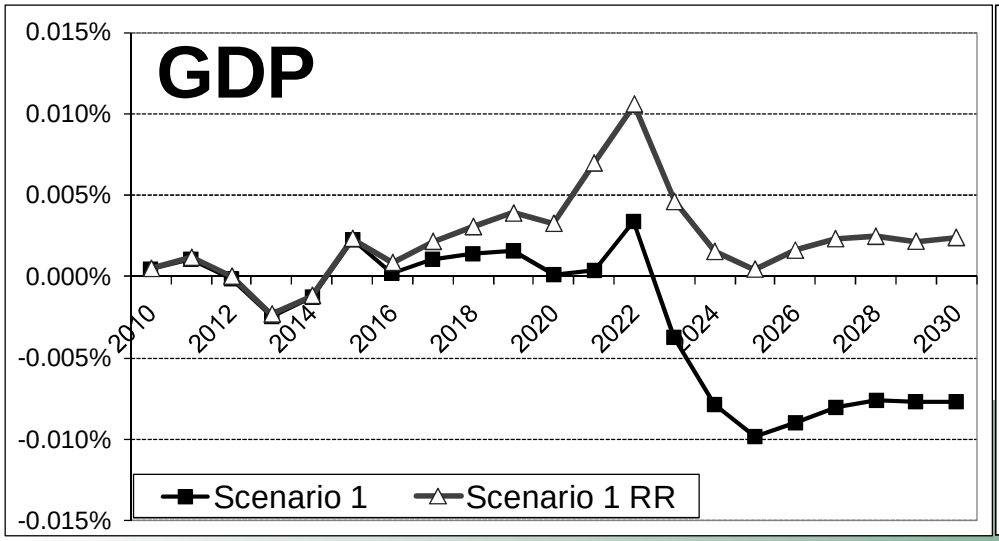
Employment

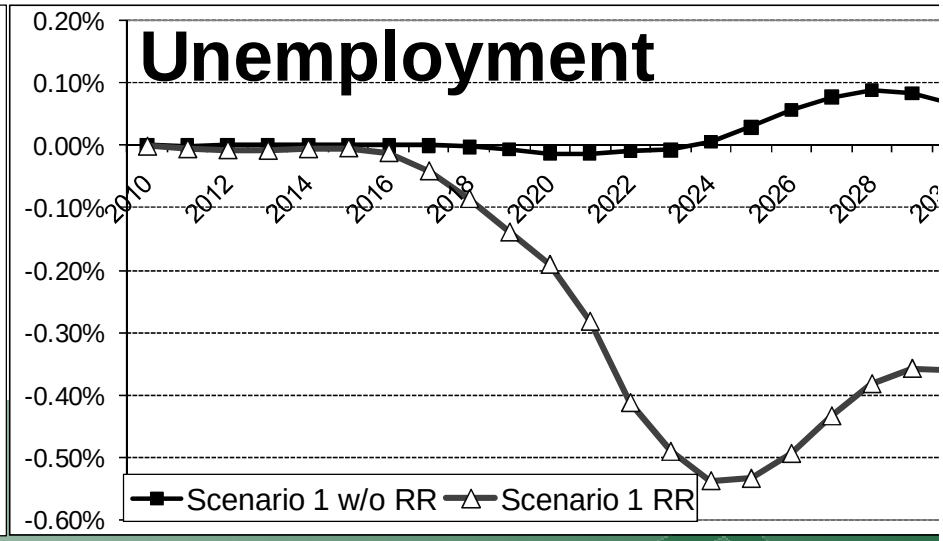
- Scenario 1: small increase in employment over 2018-2022, then the employment decreases up to -0.01% compared to BAU; this negative effect is turned over since 2029
- Neutral effect of Scenario 2



SCENARIO 1> Revenue recycling…

- saves emission & energy during 2016-2025, then yields minor rebound effect since 2025
  - *difference in total –compared to 'w/o RR' scenario– is negligible [<0.01%], max for coal [up to +1%]*
- turns activity, consumption and output falls into its increases
- switches unemployment effect into the employment gains





SCENARIO 1

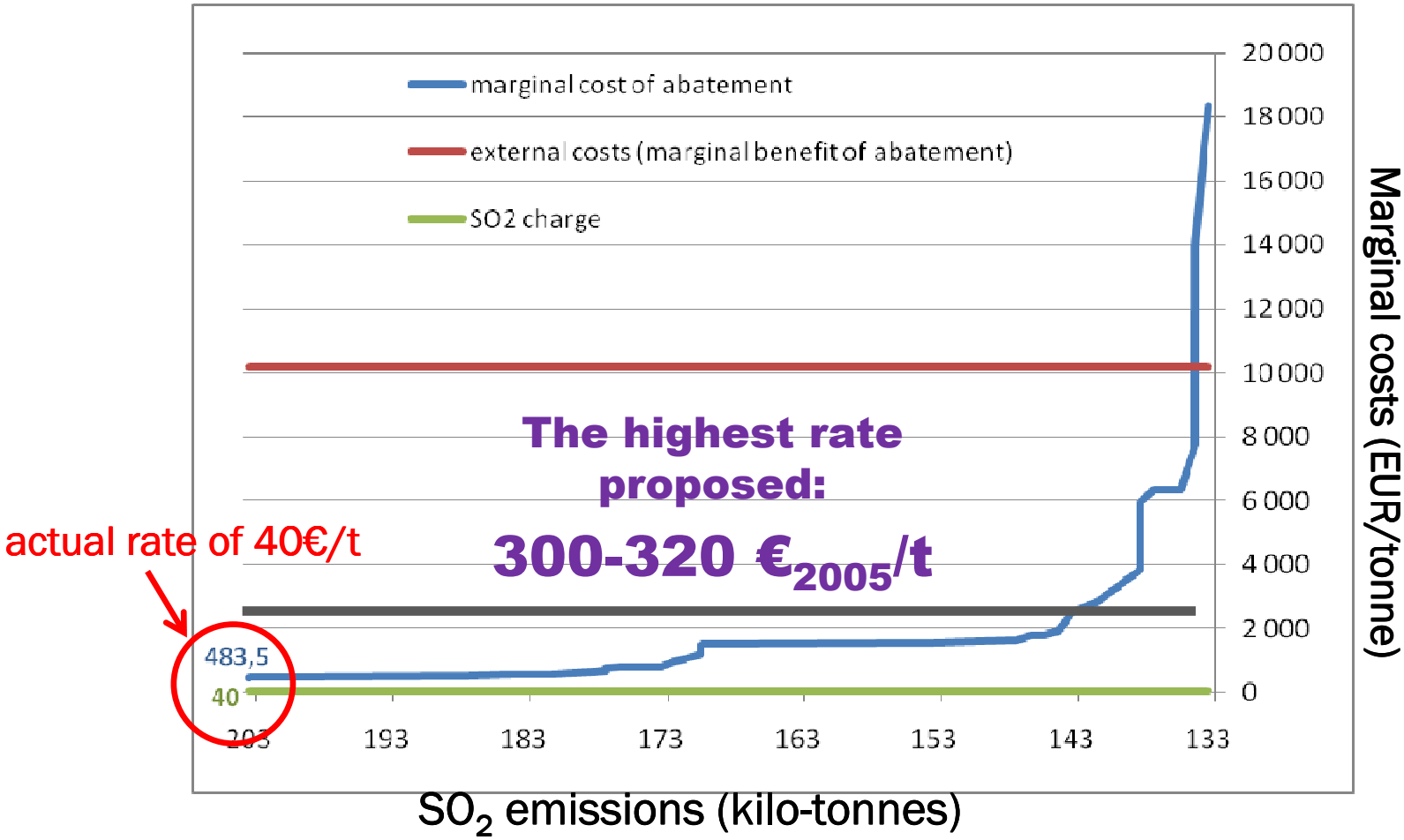
Revenue recycling effect on employment…

	2016	2020	2024	2028
1 Agriculture etc	-1	70	185	-50
5 Food, Drink & Tob.	4	6	17	58
6 Text., Cloth. & Leath	0	2	11	20
7 Wood & Paper	2	13	31	26
12 Rubber & Plastics	3	37	78	41
13 Non-Met. Min.	0	20	67	58
18 Elec. Eng. & Instrum.	0	9	28	23
19 Motor Vehicles	1	7	33	57
20 Oth. Transp. Equip.	0	2	4	3
21 Manuf. nes	4	25	38	19
25 Construction	3	109	321	318
27 Retailing	0	8	29	36
28 Hotels & Catering	1	4	28	65
29 Land Transport etc	0	55	152	-4
37 Other Bus. Services	0	15	66	96
41 Misc. Services	27	291	767	530
Total	**47**	**696**	**1924**	**1372**
	0.001%	**0.014%**	**0.039%**	**0.028%**

Conclusions

- macro-econometric E3ME model updated and extended for 3E forecasting and policy scenario assessment over 2010-2030
- Scenario 1 –as proposed by the Czech MoE– would result in negligible effects on the economy and small effects on pollution and energy use
  - the charge rates are not effective, i.e. their level is far from MAC
  - effective to reap revenues of about 50 bln. CZK accompanied by envi benefits of 11 bln. CZK in total by 2030
- the revenue neutral scenario outperforms the scenario w/o revenue recycling wrt the effect on economy and employment
- overall effects conditional to the assumptions and BAU forecast → sensitivity analysis performed in follow up research

Máca et al.: Externalities, Abatement Costs & MBI



Application 2

Ancillary effects of carbon tax and emission charging

E3ME Applications for the Czech Republic

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  - May 2009
    - 20-40 times increase in the rates of SO_2, NOx, PM and VOC to reach MAC as derived by GEM-E3 model for CZE (Van Regemorter 2008)
  - August & November 2009
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- Carbon or pollutant abating policies → looking at ancillary effects

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- CO_2 allowance price

  exogenous price as derive by PRIMES model (DG TREN 2008) in all scenarios

Assumed Damage Costs

Derived for the emissions released in the Czech Republic by updated EcoSenseWeb tool and using an impact pathway approach (Preiss et al., 2008; also in Maca et al., 2009)

- SO2 ..... 8,371 Eur/t
- NOx ..... 9,359 Eur/t
- PM ..... 19,126 Eur/t
- NH3 ..... 21,962 Eur/t
- VOC ..... 990 Eur/t

Cost of Climate Change

- CO2 ..... 20 Eur/t
- various impact assessment models report a wide range of CO2 damage cost magnitudes
- uncertain effects, enhanced adaptation of the system in the long-run, assumptions on a discount rate, a form of discount function and equity weighting, which an analyst has to decide only arbitrarily on.

Scenario 1: emission charging, € per t

	Actual rates 1997-09	2010	2012	2013	2014	2015	2016-2020
Particulates	106	148	803	1 458	2 113	2 768	3 422
SO_2	35	49	152	255	358	462	565
NOx	28	40	257	475	693	911	1 129
VOC	71	99	764	1 428	2 093	2 758	3 422

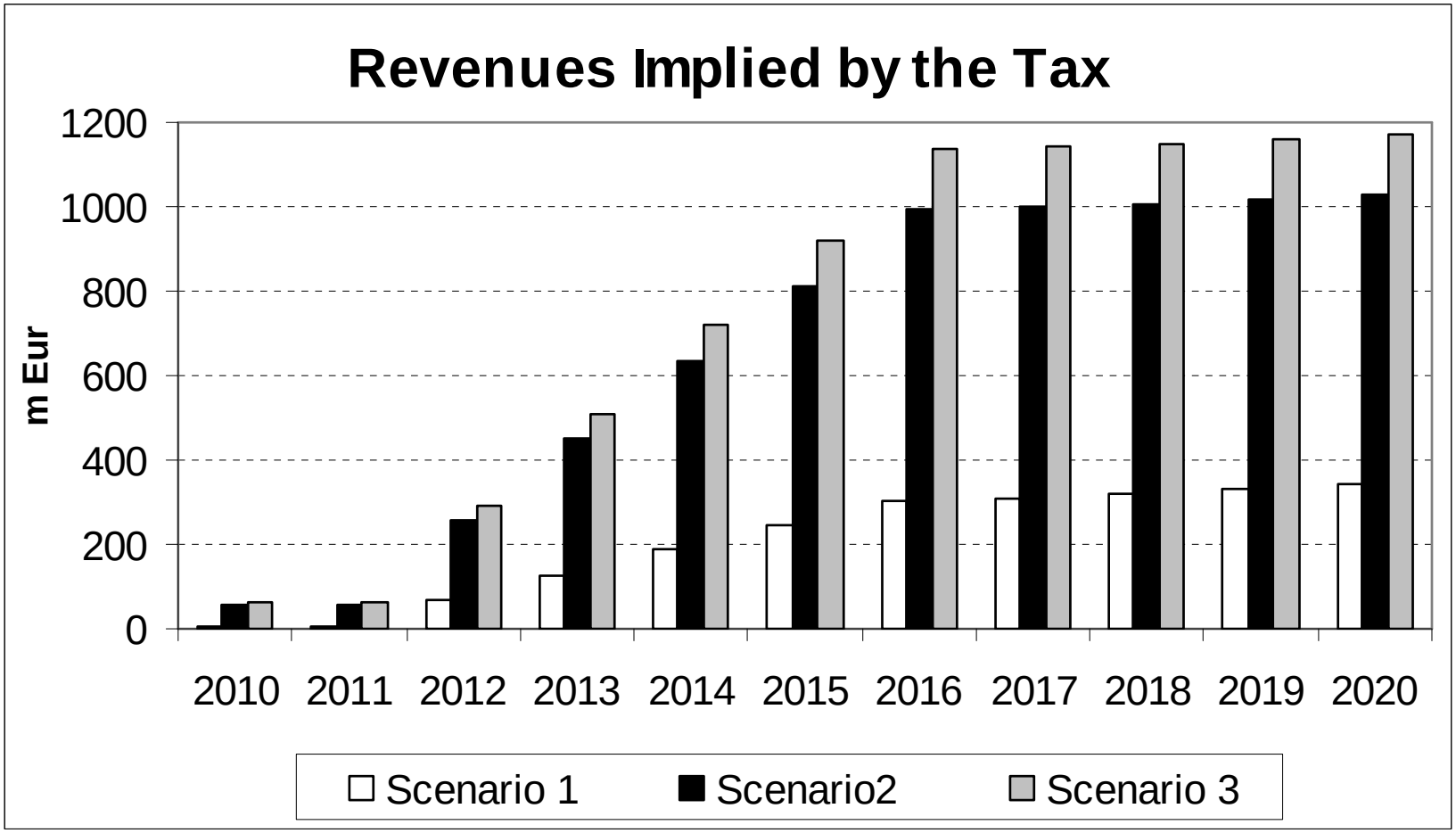
Rates are determined at the level to reach **marginal shadow prices**, i.e. marginal abatement costs, as derived by the GEM-E3 CGE model for the reference with the climate/energy 2020 package (Van Regemorter, 2008)

- they involve reaching the national emission ceilings in the Czech Rep.
- a significant increase (NOx 40 times)
- transport, non-energy use and households are not subject to taxation

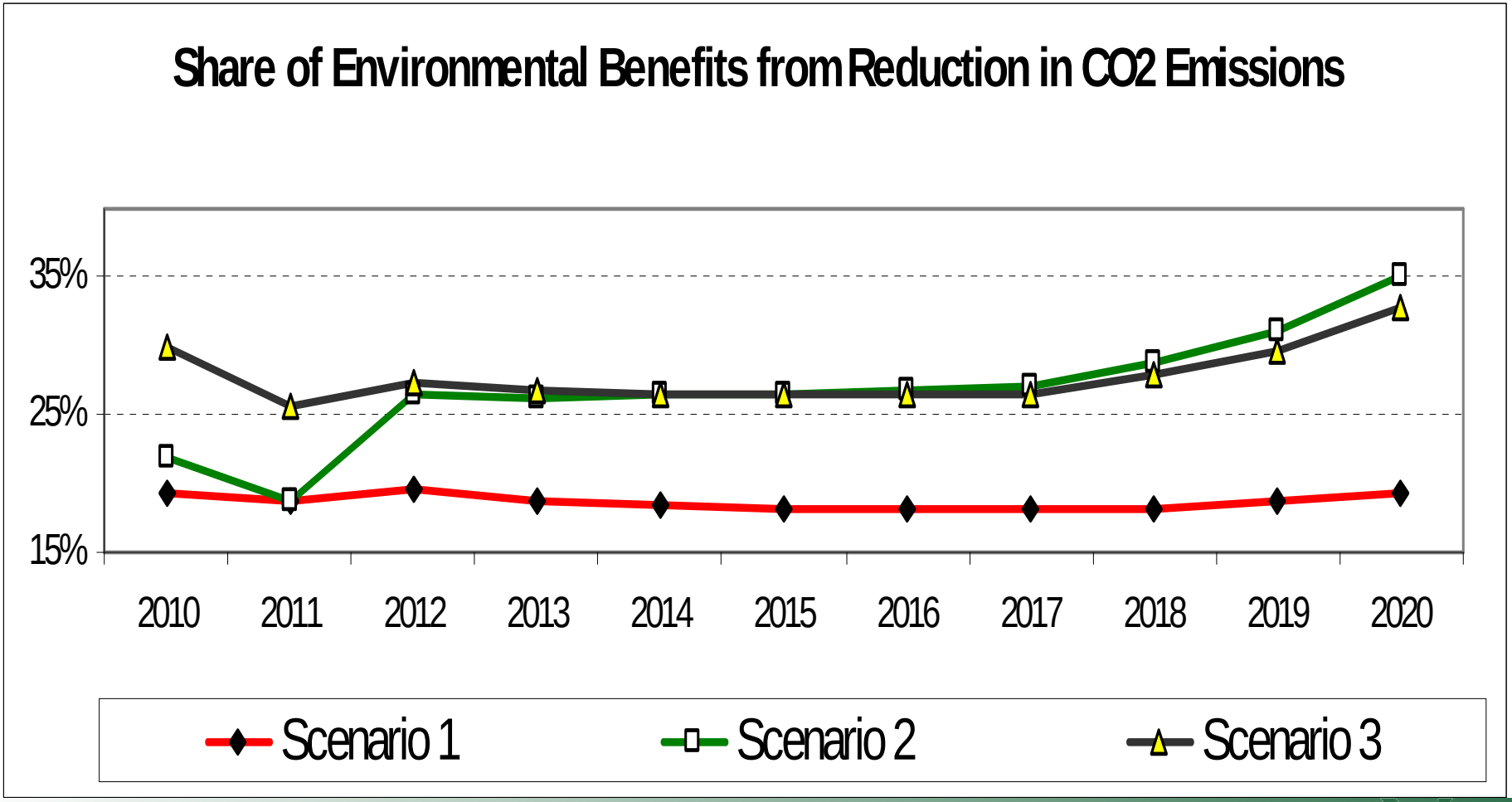
Scenario 2 & Scenario 3
EUR per t CO_2

	Actual rates 1997-2009	2010	2012	2013	2014	2015	2016-2020
Scenario 2 (stacionary sources only)							
Carbon tax	n.a.	0.7	3.2	5.8	8.3	10.8	13.3
Scenario 3 (stacionary sources and transport)							
Carbon tax	n.a.	0.6	3	5.3	7.6	9.9	12.2
EU ETS reference							
Allowance price	n.a.	19.0	20.0	20.5	21.0	21.6	22.1

Revenues generated by the tax



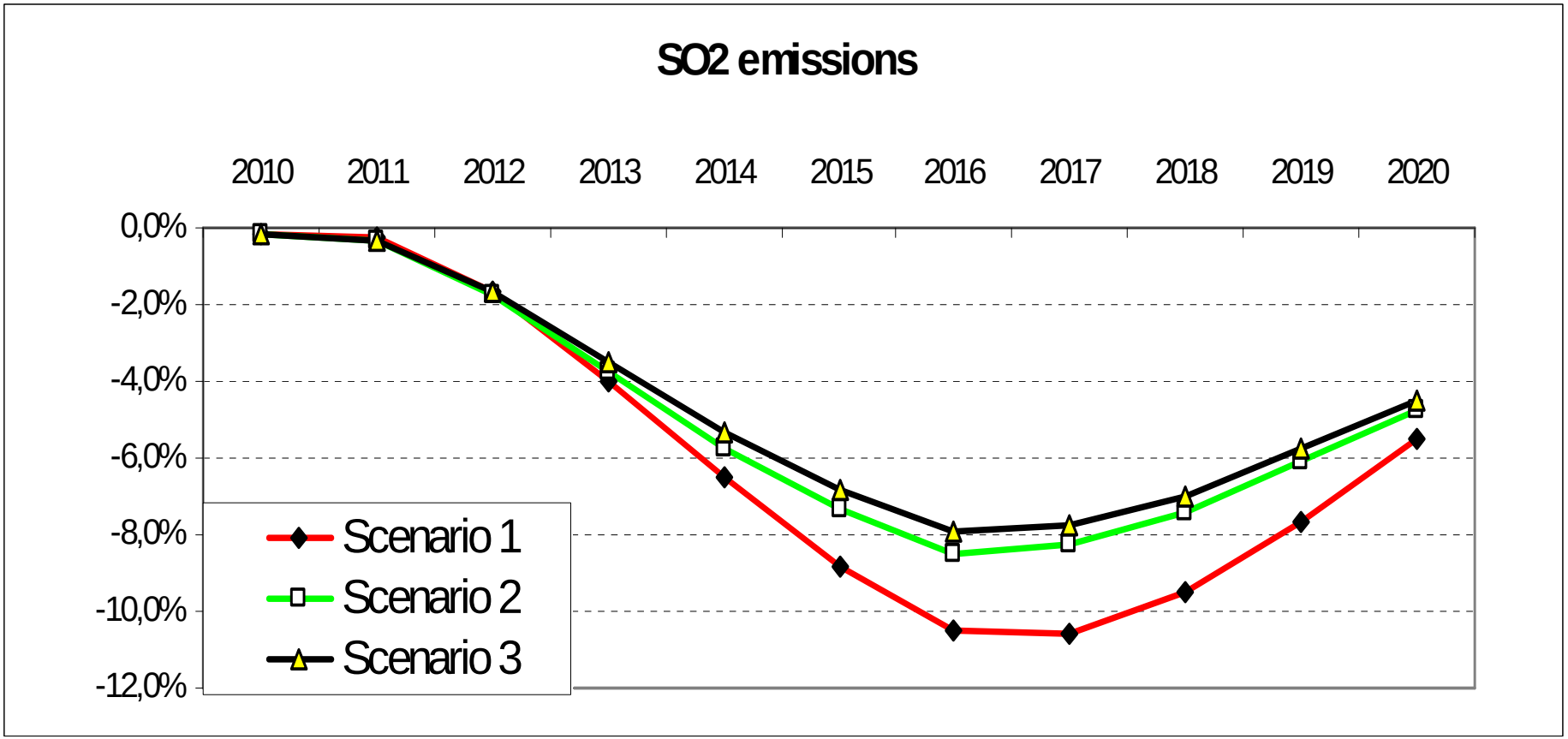
Scenarios Results: Share of avoided external costs from CO2 emissions



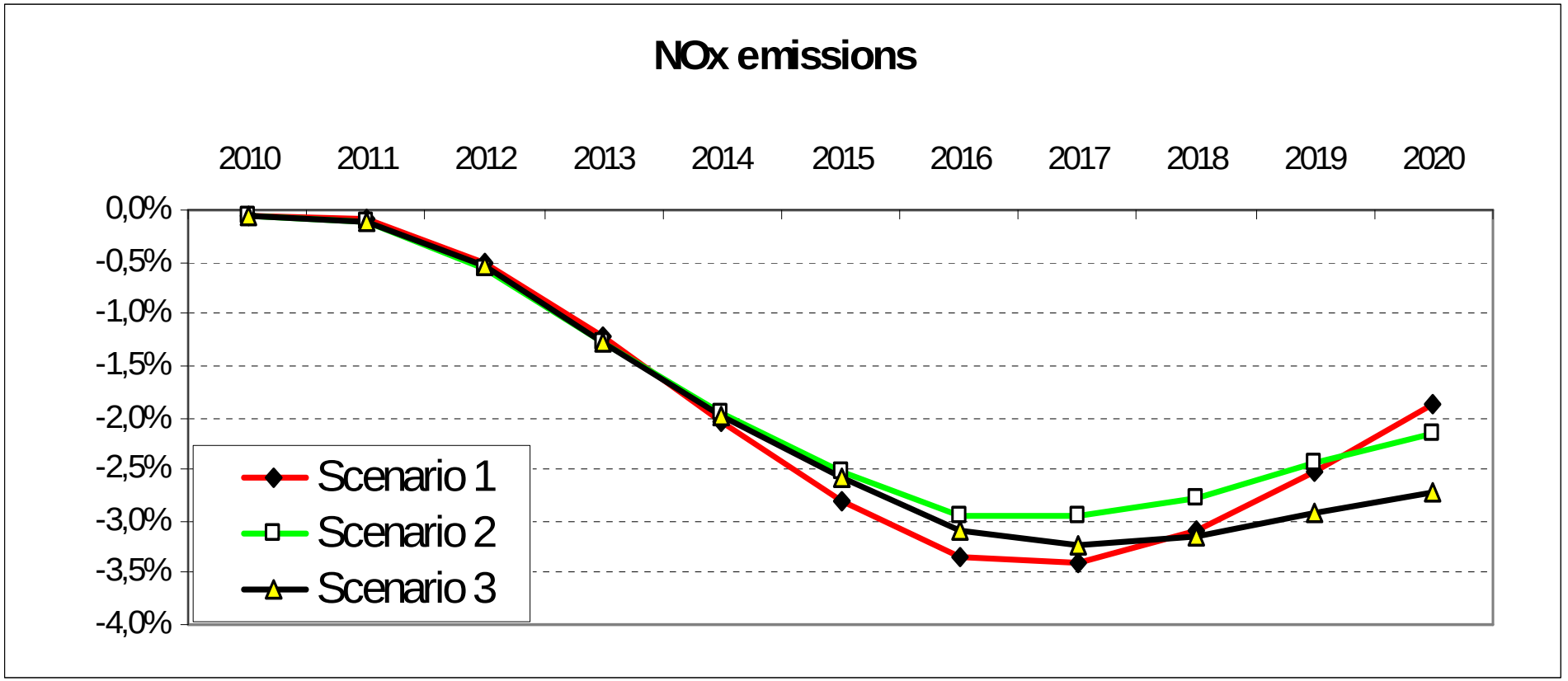
Shares of Direct and Indirect Benefits

- Scenario 1 – reduction of taxed pollutants contribute about 80% of the total savings in external costs
- Scenario 2 or Scenario 3 - reduction in non-taxed pollutants contribute 65% to 80% of total environmental benefits.
- Ancillary effects (co-effects) presents only about 23% of direct environmental benefits (approx. 18 % of sum of environmental benefits) for the Scenario 1
- Ancillary effects are almost 2.5 times larger than the direct effects for the scenarios 2 and 3
- Neglecting ancillary effects would thus result in underestimation of environmental benefit

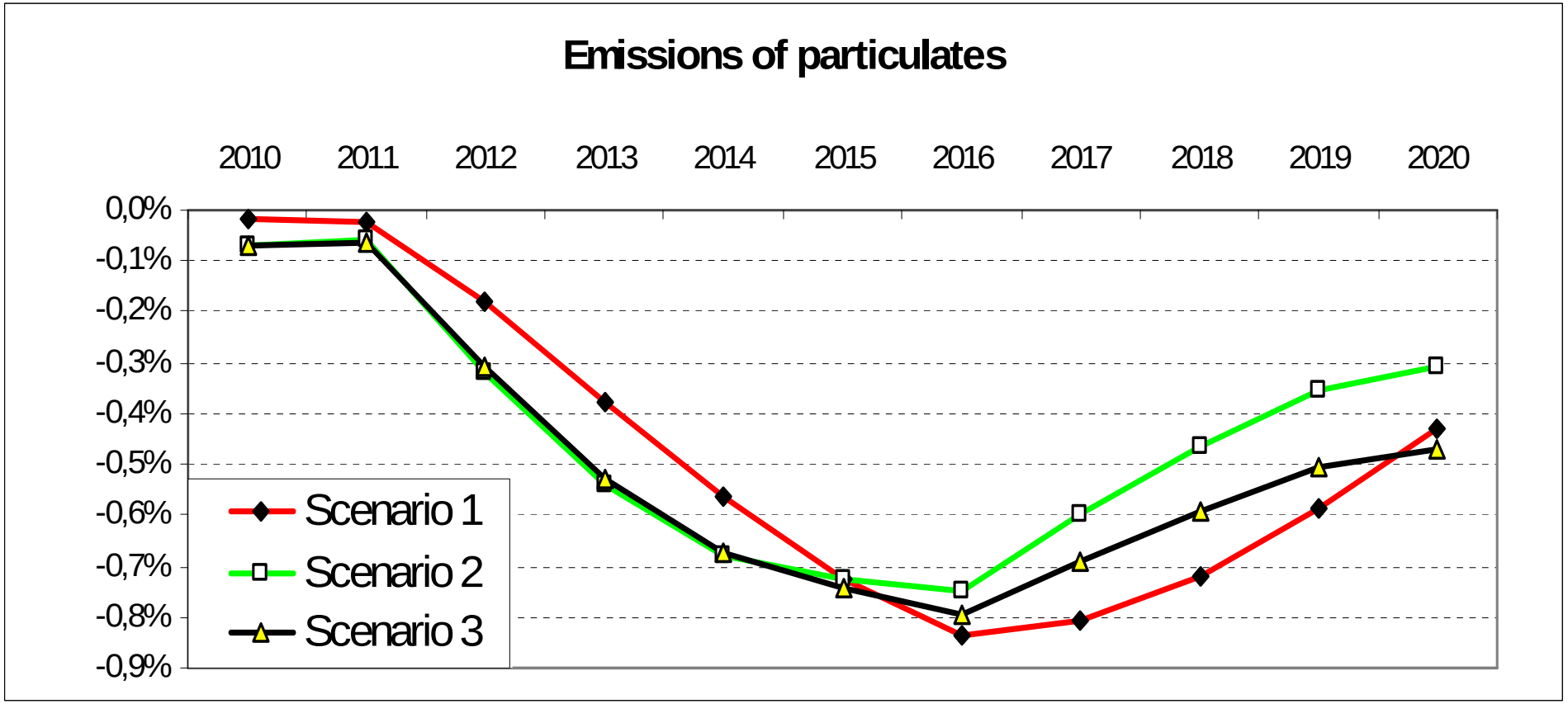
Reduction in Emissions SO2 – comparison with BAU scenario



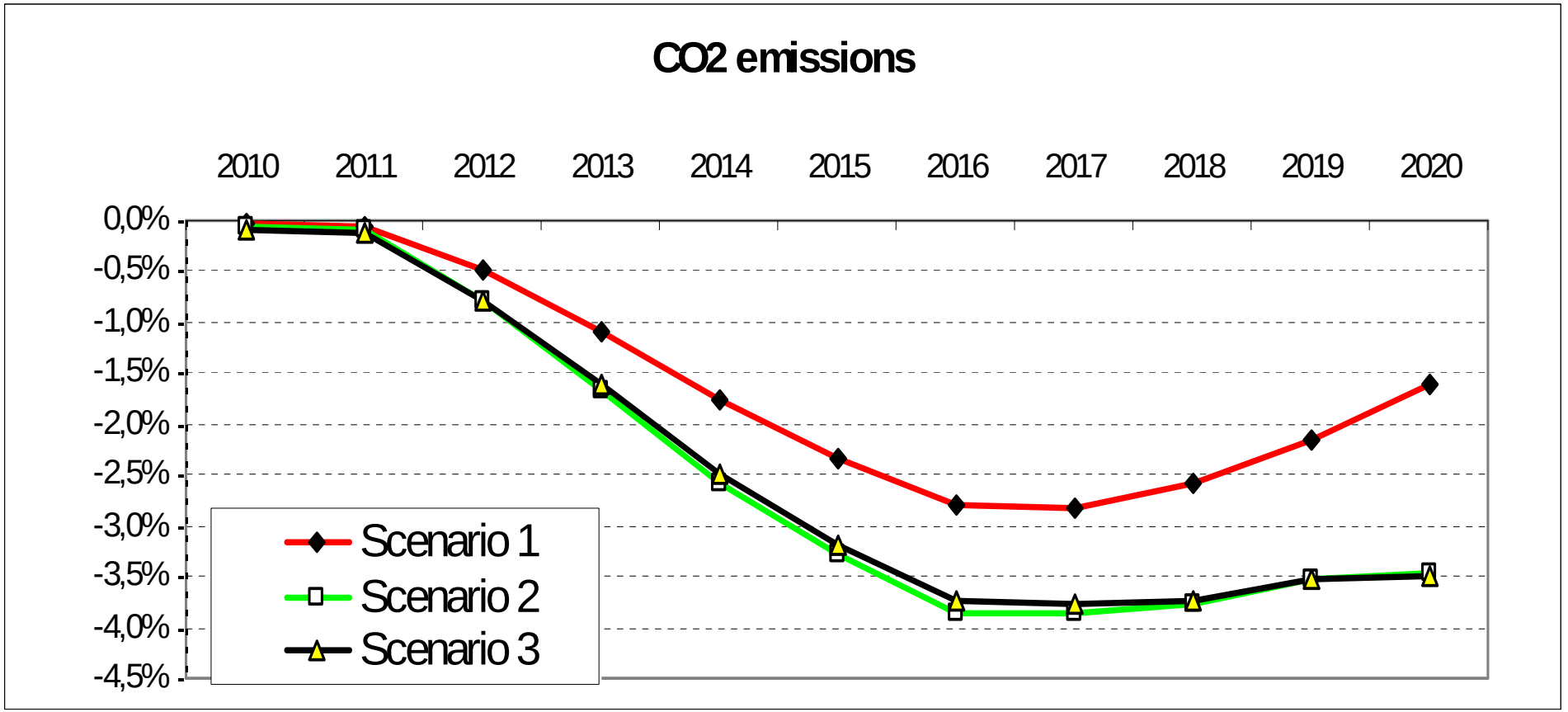
Reduction in Emissions NOx – comparison with BAU scenario



Reduction in Emissions PM – comparison with BAU scenario



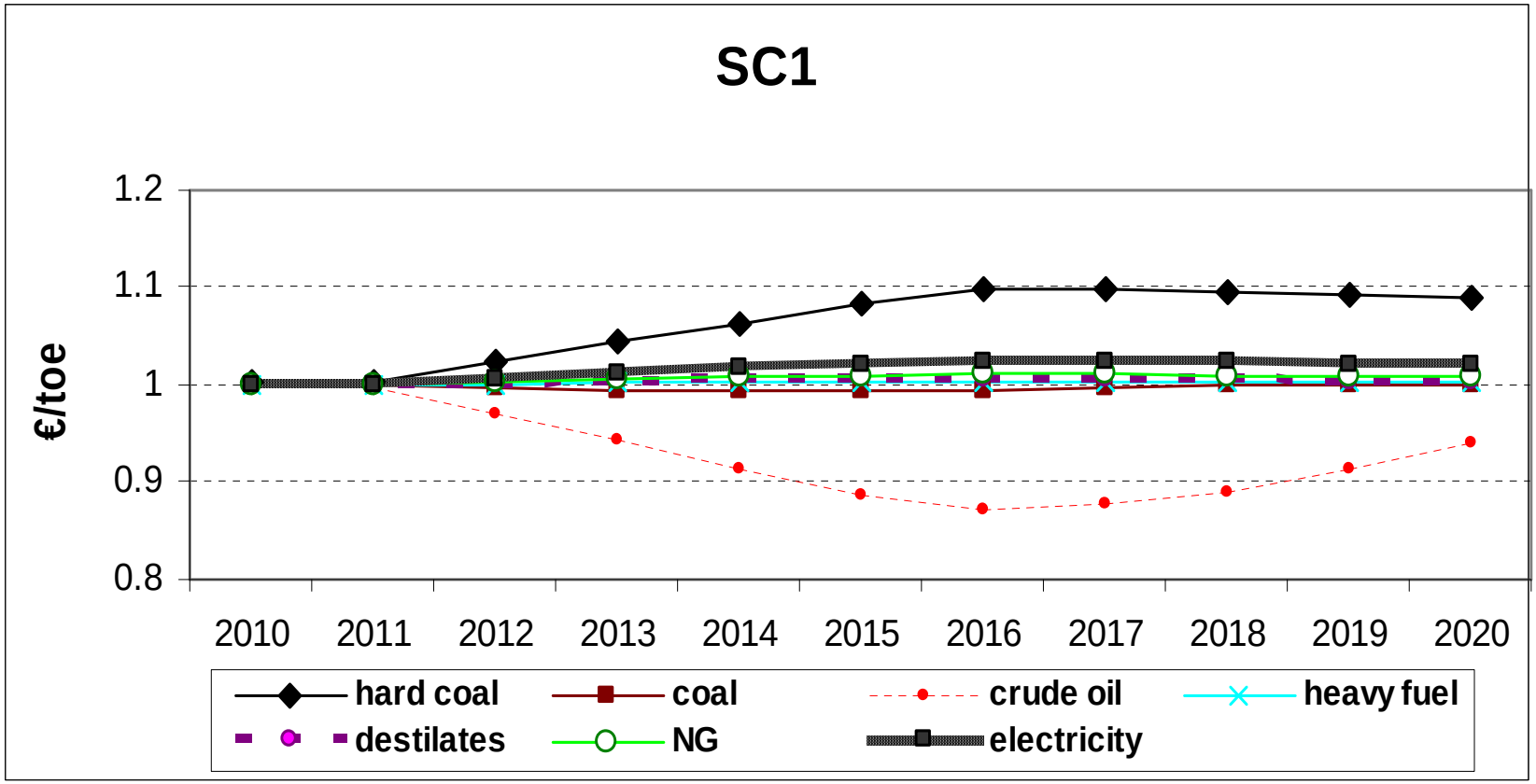
Reduction in Emissions CO2 – comparison with BAU scenario



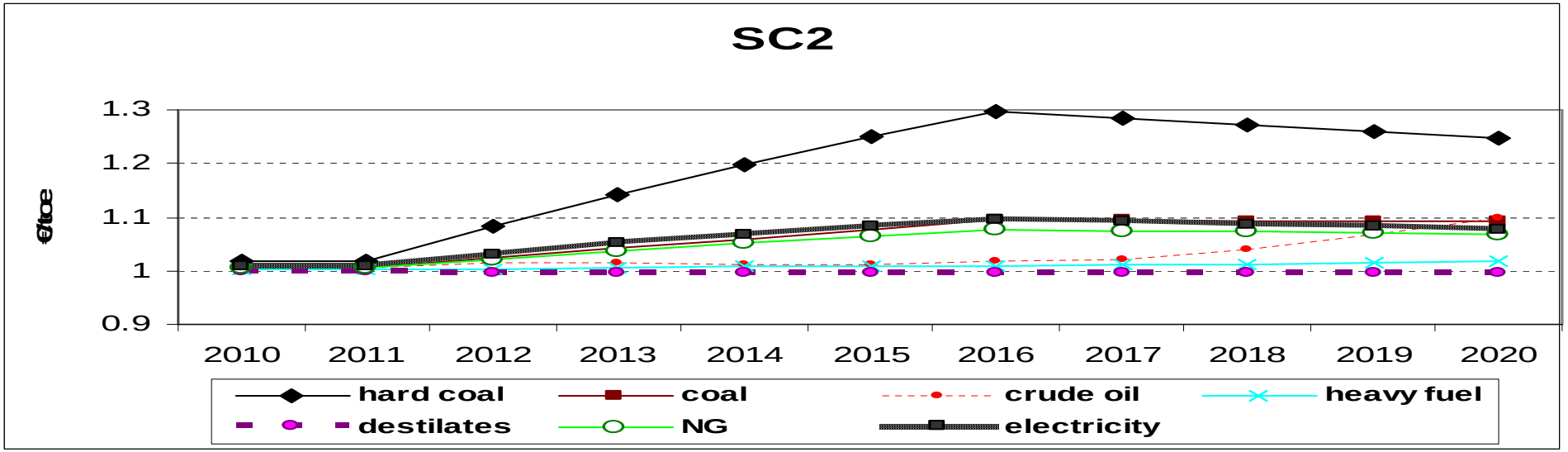
Emission Results: Comparison with BAU

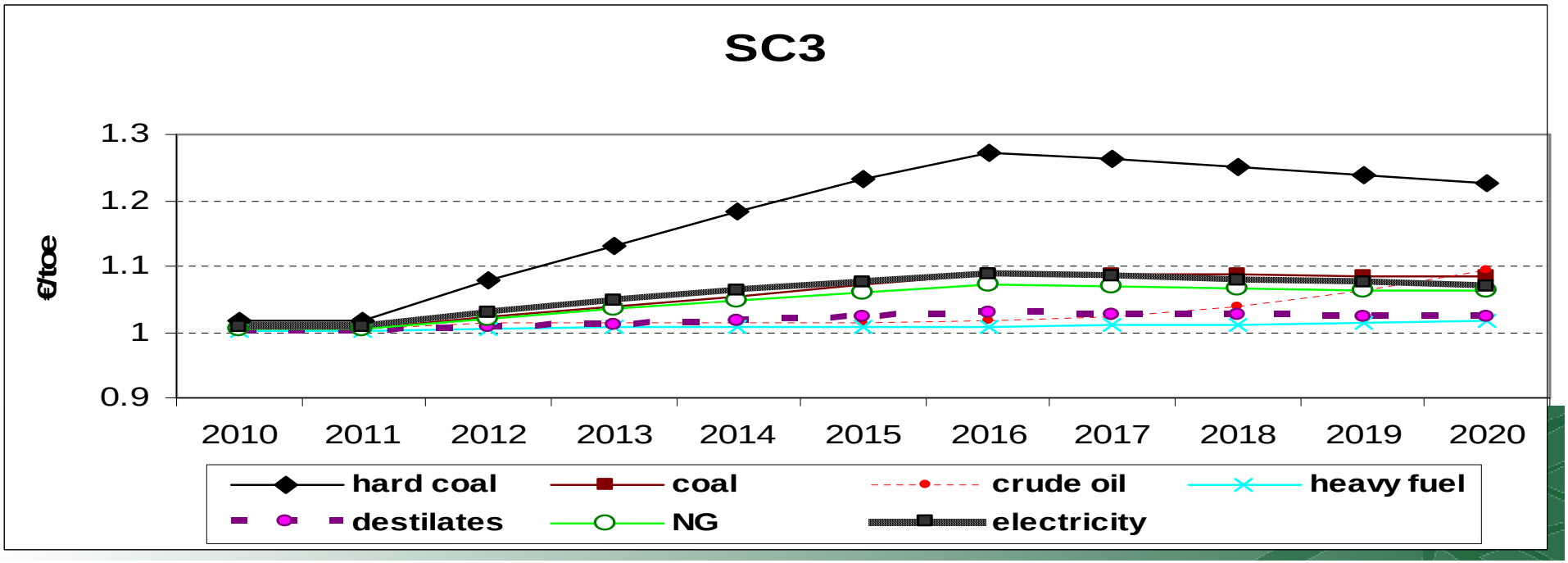
- Strongest effect for SO2 emissions in the period when the real rates reach their maximum (by almost 11% in *Scenario 1* to 8% for carbon scenarios),
- In all cases, gradual increases in charges/taxes causes emissions to reduce,
- The U-shape of the emission reduction curve (due to the price level increase, the rates will start to fall after 2017 in real terms and the economy adapts to the exogenous (policy) shock,
- Policy aiming at air quality (Scenario 1) results in a relatively large decrease in emissions of classical pollutants, while carbon-specific policies (Scenario 2 and 3) decrease relatively more the emissions of CO2

Prices of Energy Products – Scenario 1

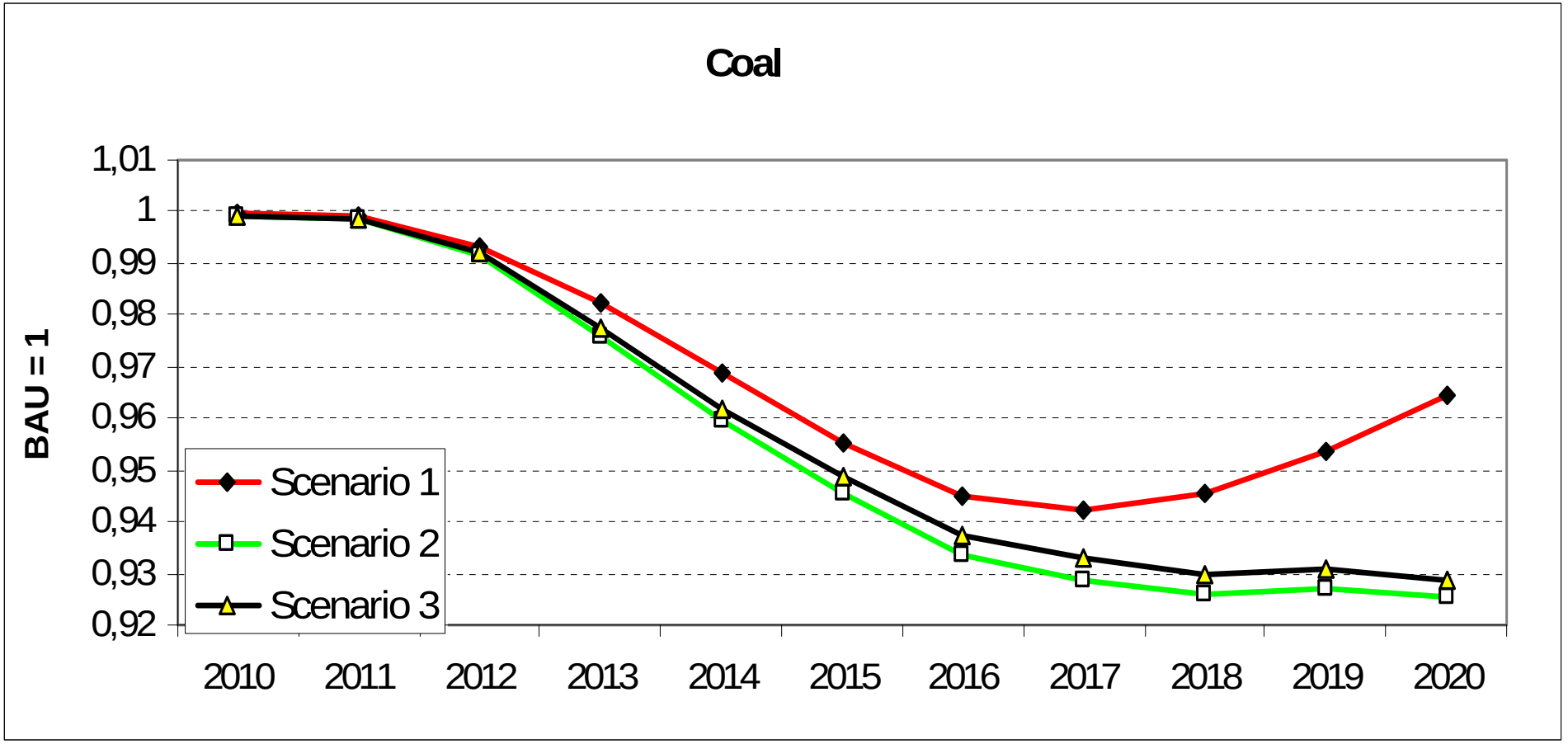


Prices of Energy Products – Scenario 2 and 3

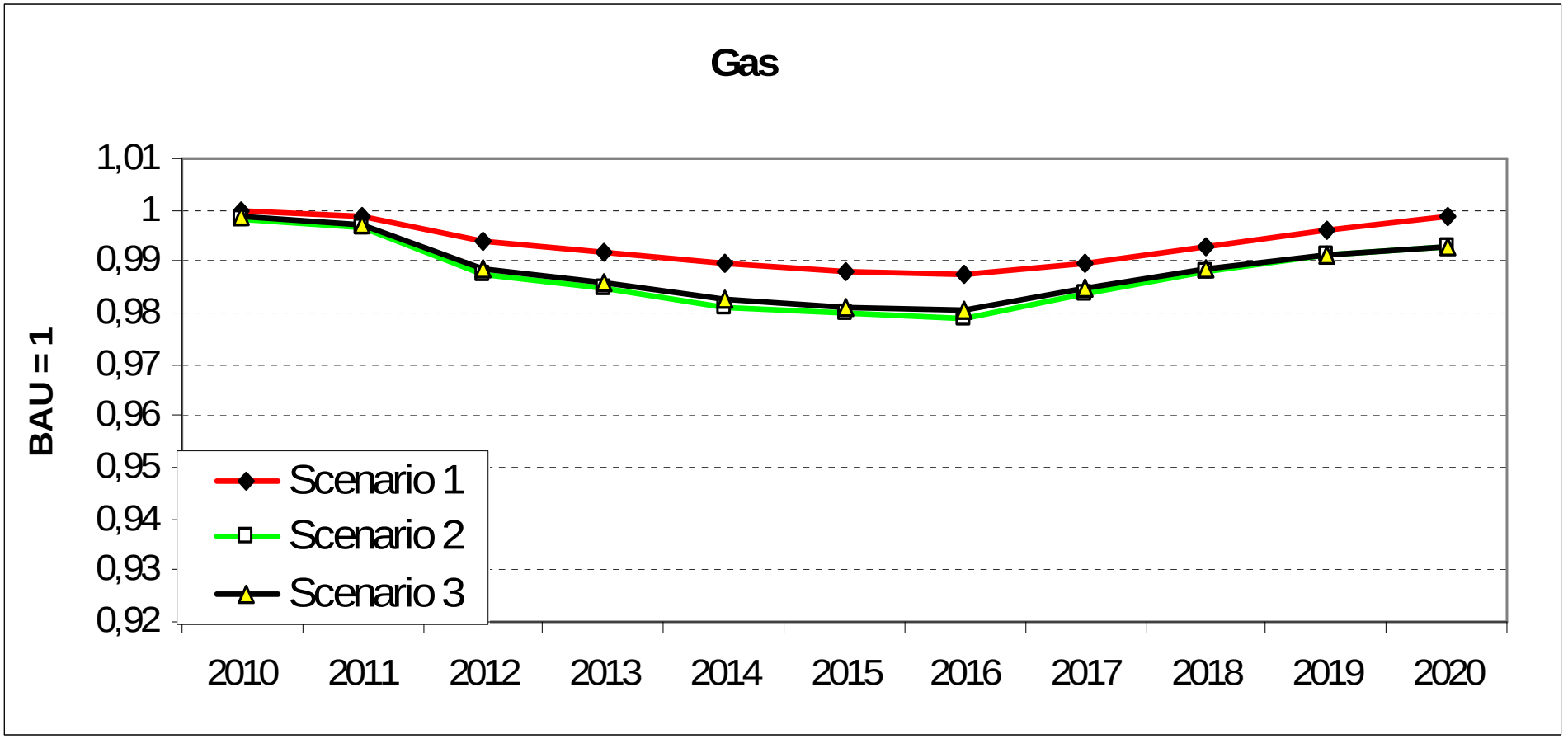




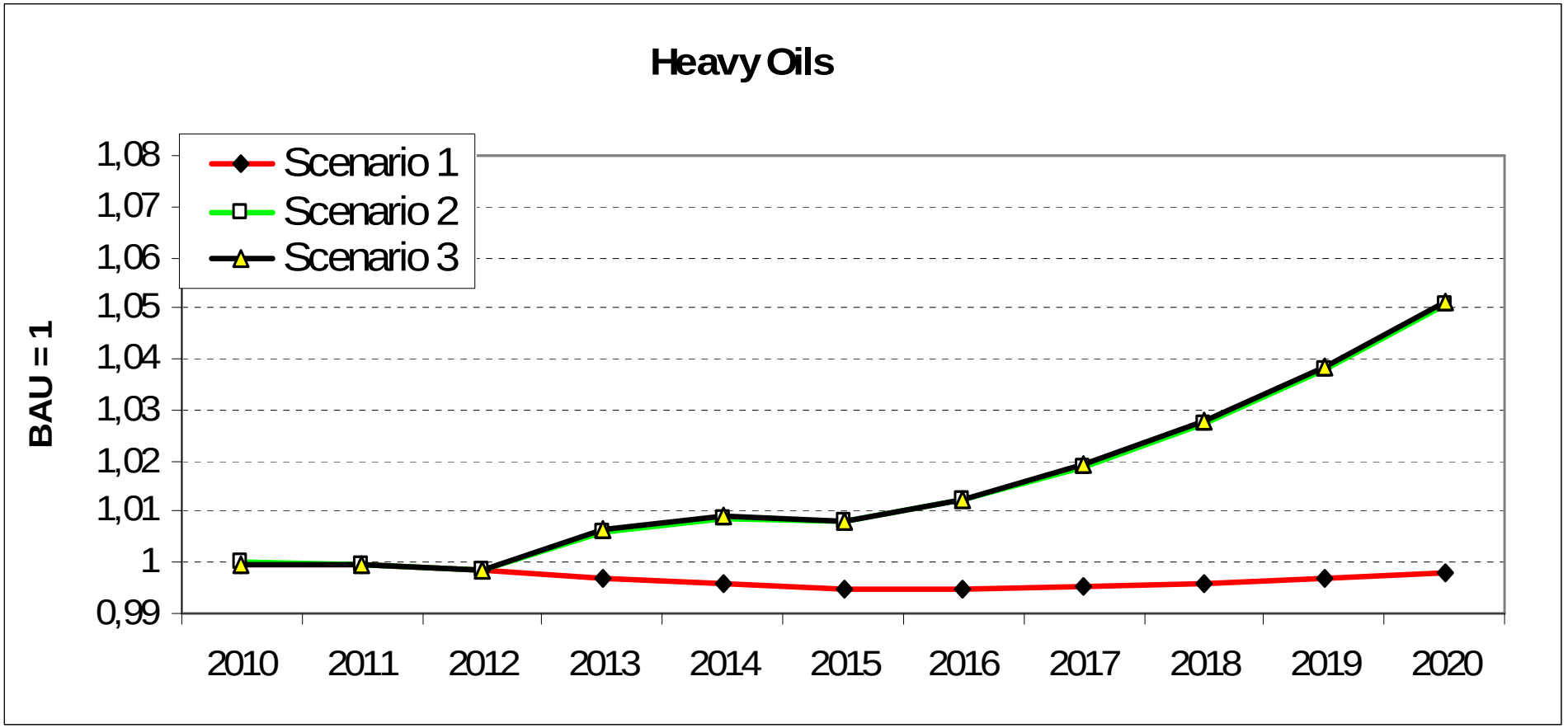
Energy Use of Coal



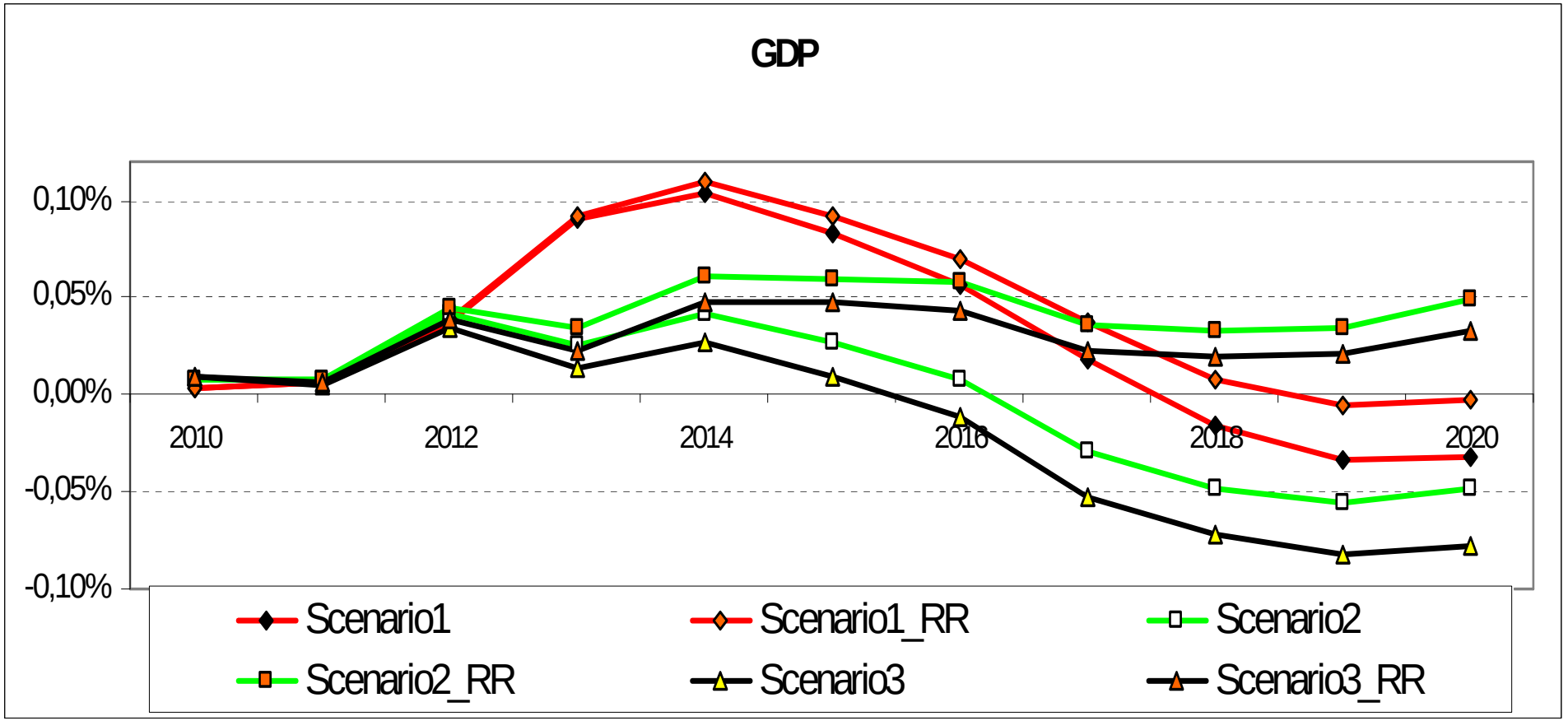
Energy Use of Gas



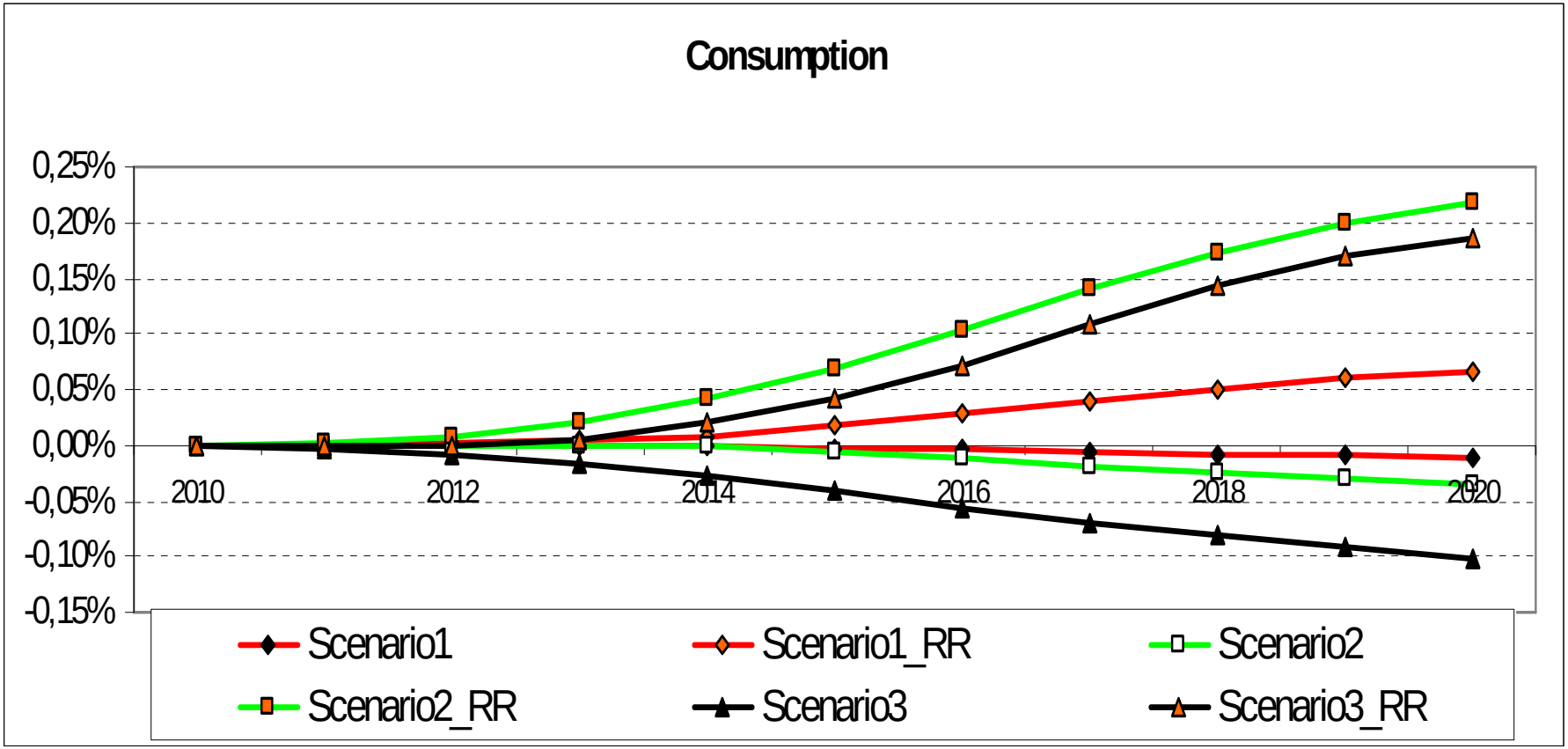
Energy Use of Heavy Oils



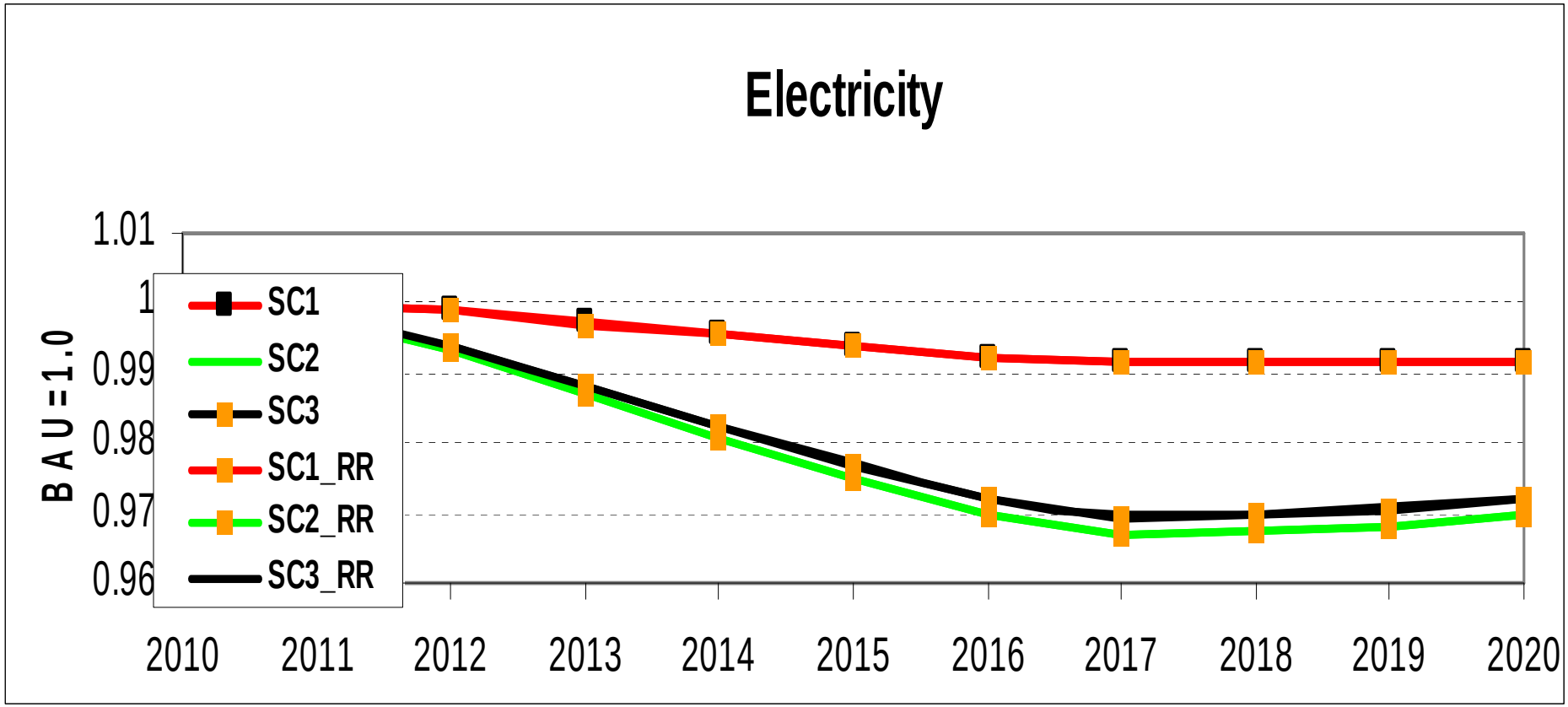
GDP and Revenue Recycling



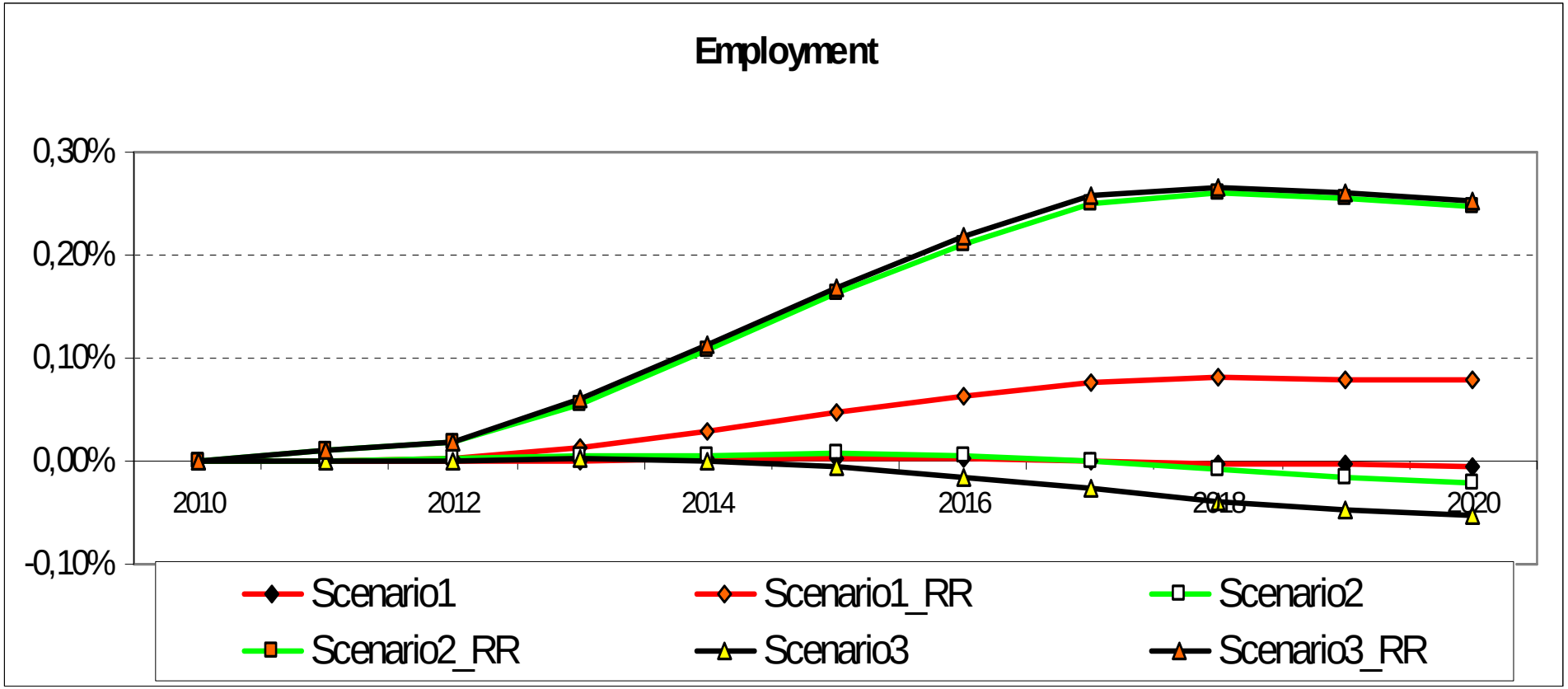
Impacts on Aggregate Consumption



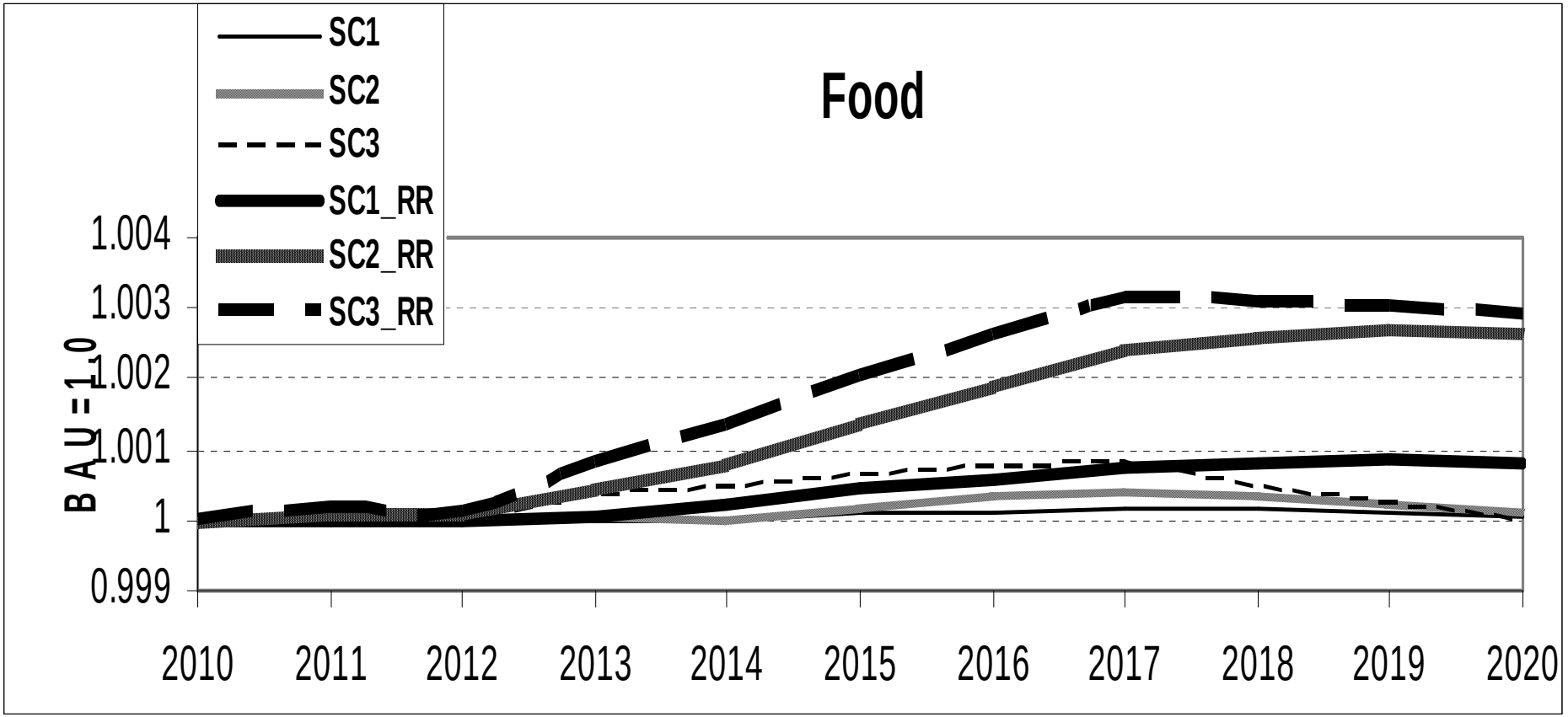
Consumption of Electricity



Impacts on Employment: Revenue Recycling



Consumption of Food



Conclusions

- *The comparison of economic impacts of both considered policy set ups indicates that policy aimed at the taxation of classical pollutants outperforms carbon policies in cases without revenue recycling.*

- *mainly due to significantly higher revenues from carbon taxation, when the revenues are recycled, a carbon taxation framework appears to be a better option*

Thank you for your attention!

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