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GHG Mitigation Strategies in Context of the Bulgarian Energy Future

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Objectives of this lecture

- To demonstrate an approach for analysis
- To present results for a specific case study
- To provide basis for discussion on the alternative response to climate change

Note: The case study, presented herein is elaborated based on publicly available data on the energy sector, GHG emissions, discussed post-Kyoto strategies. The study does not consider all possible scenarios for future development. The study is based on forecasts for energy demand, fuel prices, GHG emission prices, etc. Therefore the results of the study shall be considered illustrative and for information purposes only. The study presents the view of the authors, and does not represent an official statement of the Bulgarian government.

OVERVIEW

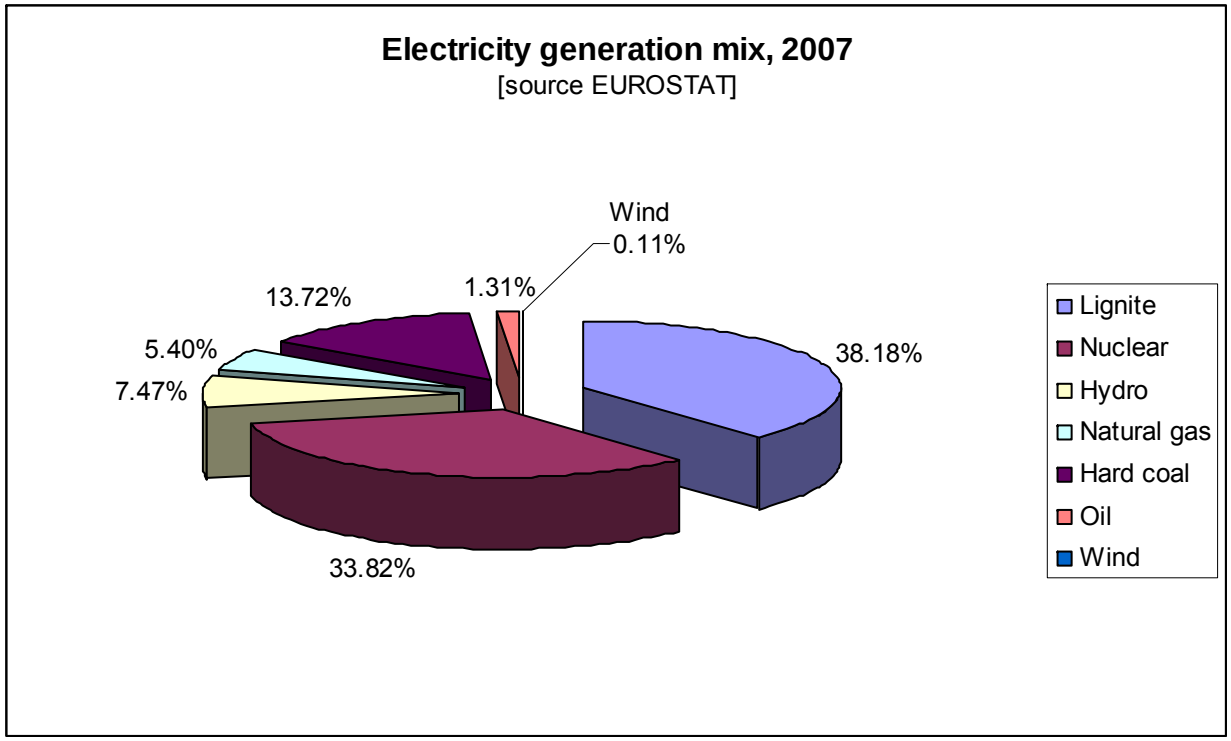
EU objectives

- To reduce GHG emissions by 20% until 2020 compared to 1990 level;
- To increase the share of energy from renewable sources to 20% until 2020;
- To improve energy efficiency by 20% until 2020.

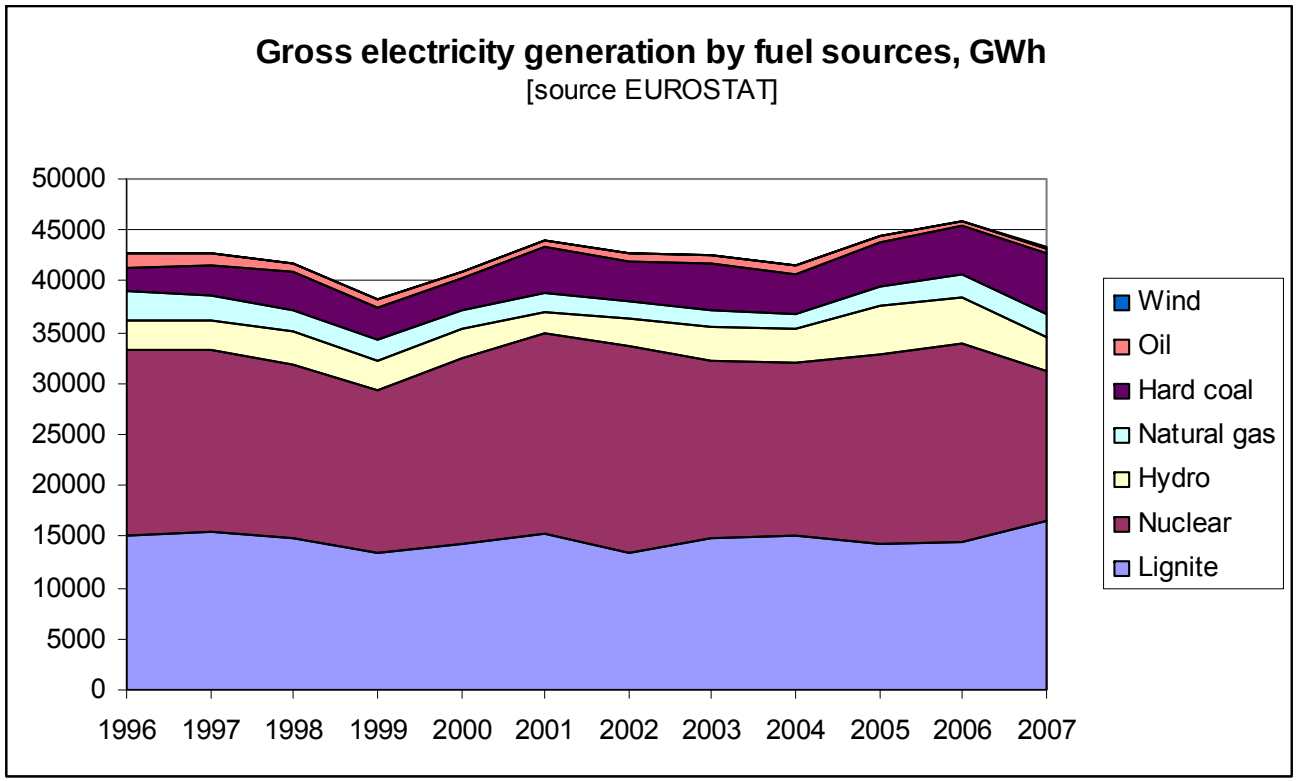
Commitments of Bulgaria

- Kyoto ratified, base year 1988, 8% reduction in 2008 – 2012
- National Action Plans
- National Allocation Plan (for 2007, and for 2008-2012)
- National reports on CO_2 emissions

Energy Mix (status 2007)



Energy Mix, 1996 - 2007



CASE STUDY

Approach for Analysis

- Screening of approaches and selection for analysis
- Development of a full energy system model in MESSAGE modelling framework
- Detail evaluation of the screened/short-listed proposals for post-Kyoto period and the proposed targets for GHG reduction up to 2020.
- Estimation of economic burden and opportunities under various post-Kyoto regimes.

Selected approaches

- Absolute Binding Target
- Dual Target
- Price Cap
- Carbon Tax

Base case

- No emission reduction targets
- No limits other than availability of resources

MESSAGE Model Characteristics

- Timeframe
  - Base year 2004, First year 2007,
    First period 2007 – 2010, Last year 2050
- Modeled sectors:
  - Electricity and heat production
  - Transport
- Load regions
  - 4 seasons, 2 day types – working and weekend, 2 parts – normal and peak.
- Discount rate – 6%

MESSAGE Model Characteristics

- Available resources:
  - Local – lignite and brown coal, water, wind, solar
  - Imported – coal, natural gas, crude oil, diesel, nuclear fuel
- Installed capacities
  - TPPs on local coal, TPPs on imported coal, NPP, Gas and Oil CHPs, Hydro, PSHPP, Heating plants.
- Options for development
  - Electricity production: Rehabilitated and new plants on local coal, new plants on imported coal, new NPP, new HPP, new GCC, wind power plants
  - Heat production: new plants (extensions) for combined electricity-heat production (CHPs)
  - Transport – replacement of traditional fuel by biofuel.
- Note Carbon Capture and Storage (CCS) not envisaged.

Main restrictions

- Availability of local resources
  - Lignite – Maritsa East area
  - Brown coal – in the area of Bobov dol and Pernik
  - Water
  - Wind – wind velocity above 6.5 m/s
- Imported resources
  - Nuclear units – maximum new capacities 6000 MW until 2040, 8000 MW until 2050
  - Natural gas – 6 bln m^3 until 2015, 15 bln m^3 after 2015.

Environmental restrictions

- Sulphur emissions
- Share of renewable sources (water, wind, solar) in electricity production ~ 12% in 2020, 2025, 2030.

Absolute binding target
Definition of Target

- Base year 1988
- 20% reduction of CO_2 emissions by 2020.
- 30% reduction of CO_2 emissions by 2030.
- Emission trading
  - Emission price – middle, low, high.
  - Middle – 30 EUR/t buying, 28 EUR/t selling
  - Low – 10 EUR/t buying, 9 EUR/t selling
  - High – 60 EUR/t buying, 58 EUR/t selling

Absolute binding target
Mathematical Formulation

Objective Function

Objective Function = MIN (∑ (Fixed Costs X Available Capacities + Variable Costs x Production) + Investments in new capacities + Expenses for CO_2)

Demand Equation (Energy / Heat / Transport)

∑ Capacities x efficiencies ≥ Demand

Production/Consumption equation

∑ Production ≥ ∑ Consumption

Relation CO_2 Limit

∑ Extraction / Import technologies x CO_2 factors – Buy + Sell ≤ Absolute Binding Target

Absolute binding target
Modeling

MESSAGE Model

- Restriction on CO_2
  - Upper Limit=Absolute Binding Target
- Entries for the restriction
  - All technologies for extraction or import of fossil fuel
- Variables
  - Buy – entered in CO_2 restriction with sign “–”
  - Sell – entered in CO_2 restriction with sign “+”
  - Cost of variables – equal to buying / selling price

Dual target
Definition of Target

- Base year 1988
- Upper Limit (Buying Limit)
  - 15% reduction by 2020
  - 25% reduction by 2030

  i.e. the limit is 5 % higher than in case of Absolute Binding Target.
- Lower Limit (Selling Limit)
  - 10% lower than the Upper Limit, i.e. this limit is 5% lower than the absolute limit of Absolute Binding Target
- Emission price - 30 EUR/t buying, 28 EUR/t selling.

Dual target
Mathematical Formulation

Relation CO_2 Limit

$\sum$ Extraction / Import technologies x CO_2 factors + Sell $\leq$ Lower Limit

Penalties:

If CO_2>[Lower Limit] and CO_2<[Upper Limit] then Penalty = Zero

If CO_2>[Upper Limit] then Penalty = Cost for Buying

Dual target
Modeling

MESSAGE Model

- Restriction on CO_2
  - Upper Limit = Selling Target
- Entries for the restriction
  - All technologies for extraction or import of fossil fuel
- Variables
  - Sell – entered in CO_2 restriction with sign “+”
  - Cost of variable Sell– equal to selling price
- Penalties (multiple entry)
  - Zero if the emissions are above Selling Target and below Buying Target
  - Equal to Buying Price if emissions are above the Buying Target

Price cap
Definition of Target

- Base year 1988
- Bounding Limit
  - 20% reduction by 2020
  - 30% reduction by 2030
- Price CAP
  - Low CO2 price – 20 euro/ton
  - Mid CO2 price – 30 euro/ton
  - High CO2 price – 40 euro/ton

Price cap
Mathematical Formulation

Relation CO_2 Expenses

CO_2 emissions = $\sum$ Extraction / Import technologies x CO_2 factors

If CO_2>[Upper Limit] then Penalty = Price CAP

Price cap
Modeling

MESSAGE Model

- Restriction on CO_2
  - No Limit is imposed
- Entries for the restriction
  - All technologies for extraction or import of fossil fuel
- Penalties (multiple entry)
  - Equal to Price CAP if emissions are above the Bounding Limit

Carbon Taxes
Definition of Target

- CO2 reduction target
  - Not imposed
- Carbon Tax
  - Base – 10 euro/ton
  - High – 20 euro/ton
  - Very high – 30 euro/ton

Carbon Taxes
Mathematical Formulation

Relation CO_2 Expenses

CO_2 Expenses = $\sum$ Extraction / Import technologies x CO_2 factors x CO_2 Tax Cost per ton

Carbon Taxes
Modeling

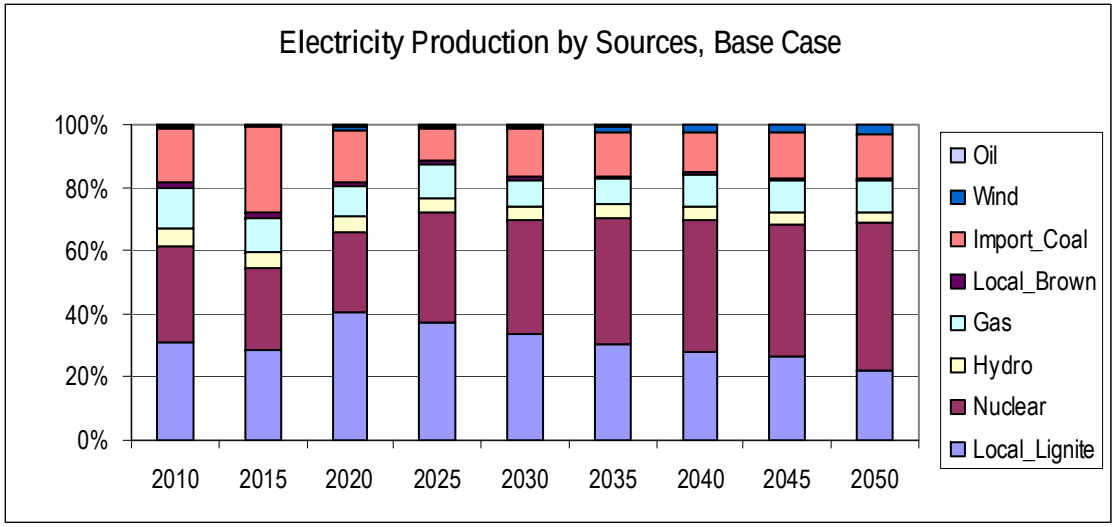
MESSAGE Model

- Restriction on CO_2
  - No Limit is imposed
- Entries for the restriction
  - All technologies for extraction or import of fossil fuel
- Cost for CO_2 emissions
  - Equal to Carbon Tax

Case Abbreviations

- *Base* – Base Case, no CO2 limits
- *ABT* – Absolute Buinding Target
  - *ABTLow* – absolute biding target with low CO2 price
  - *ABT* – absolute biding target, with middle CO2 price
  - *ABTHigh* – absolute biding target, with high CO2 price
- *DT* – Dual Target
- *PC* – Price Cap
  - *PCLow* – Price Cap, Low CO2 price
  - *PC* – Price Cap, Middle CO2 price
  - *PCHigh* – Price Cap, High CO2 price
- *Tax* – Carbon Tax
  - *Tax* – Carbon Tax, Base tax value
  - *TaxMid* – Carbon Tax, High tax value
  - *TaxMax* – Carbon Tax, Very high (maximal) tax value

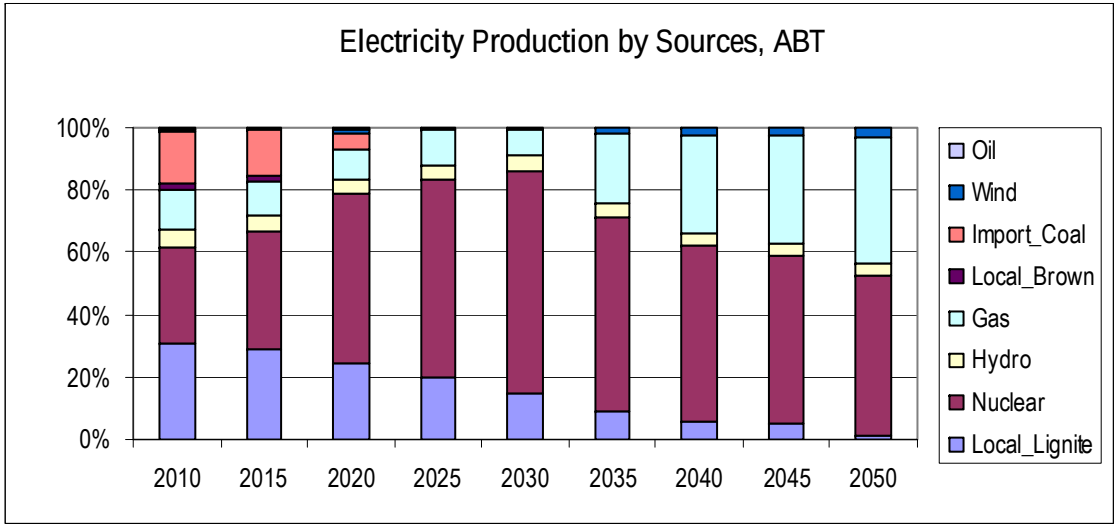
Results Base Case (1)



Results Base Case (2)

- Local lignite coal - remain one of the main sources of electricity in the country, since this is the cheapest source.
- Share of nuclear energy is expected to increase.
- Hydro energy is preferable, but is limited by available resources.
- The installed hydro capacities remain the same, and even increase by the allowed amounts, but the share in the increasing electricity demand slightly decreases.
- Gas power plants development is limited because of high gas prices.
- Local brown coal is limited by the unavailability of resources.
- Import coal is also a preferred option, with future development.
- Wind power is expensive and therefore developed only within the given lower limits, defined by the required share of renewable sources.
- Oil has a limited share currently, and new investments in oil power plants are not planned, therefore the share of oil is negligible and invisible in the graph, but added only for completeness and to allow checking of energy balances.

Results ABT (1)



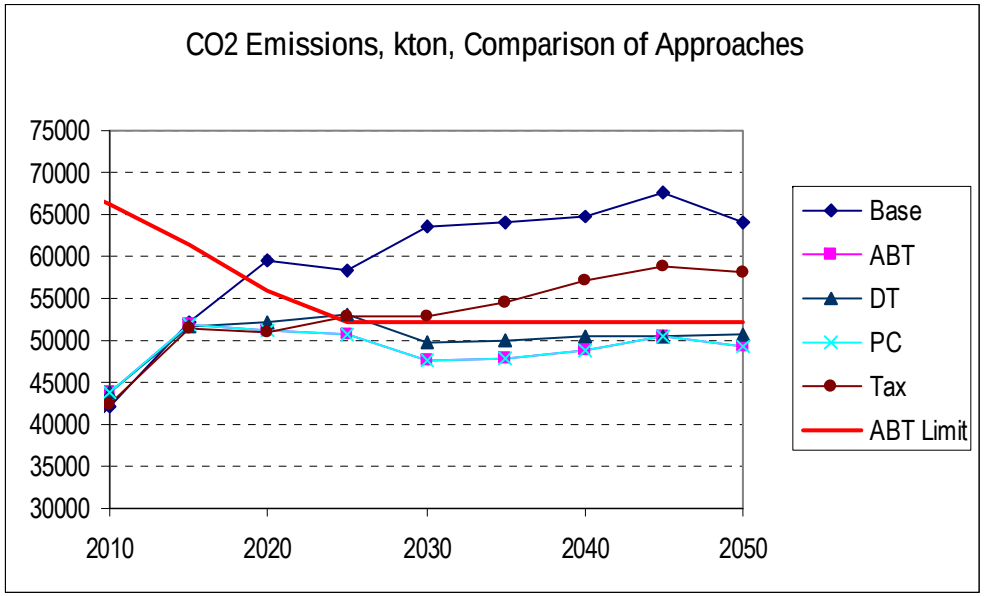
Results ABT (2)

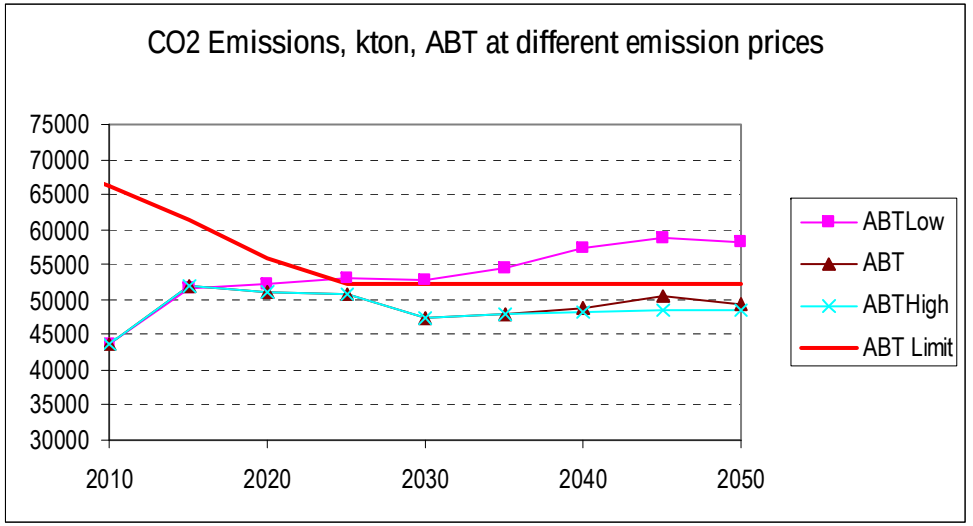
- Share of local lignite coal is decreased.
- Share of nuclear energy is increasing up to the allowed limits.
- Hydro energy is up to the limits, defined by the availability of resources.
- Share of gas power plants is significantly increased in comparison with current share and share in the Base case.
- Local brown coal is limited by the unavailability of resources, and additionally by emission restrictions, therefore completely removed after 2015 (planned rehabilitation is rejected).
- Import coal is completely excluded from the balance after the year 2020.
- Wind power is expensive and therefore developed only within the given lower limits, defined by the required share of renewable sources.
- **Conclusion: in general in case of emission restrictions, at medium price of carbon taxes, coal sources are replaced by gas and nuclear, if no CCS is foreseen.**

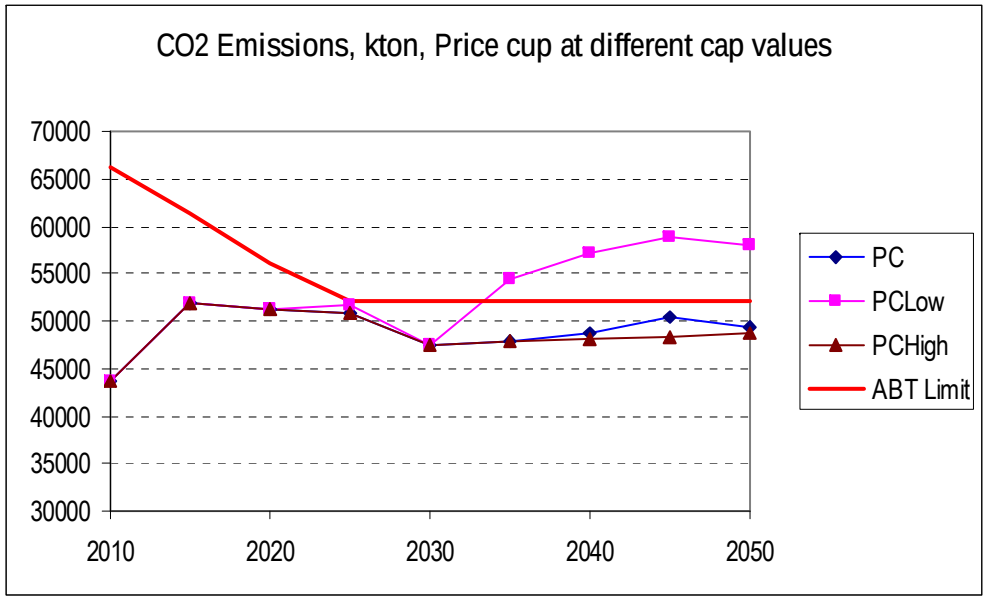
Results of other cases

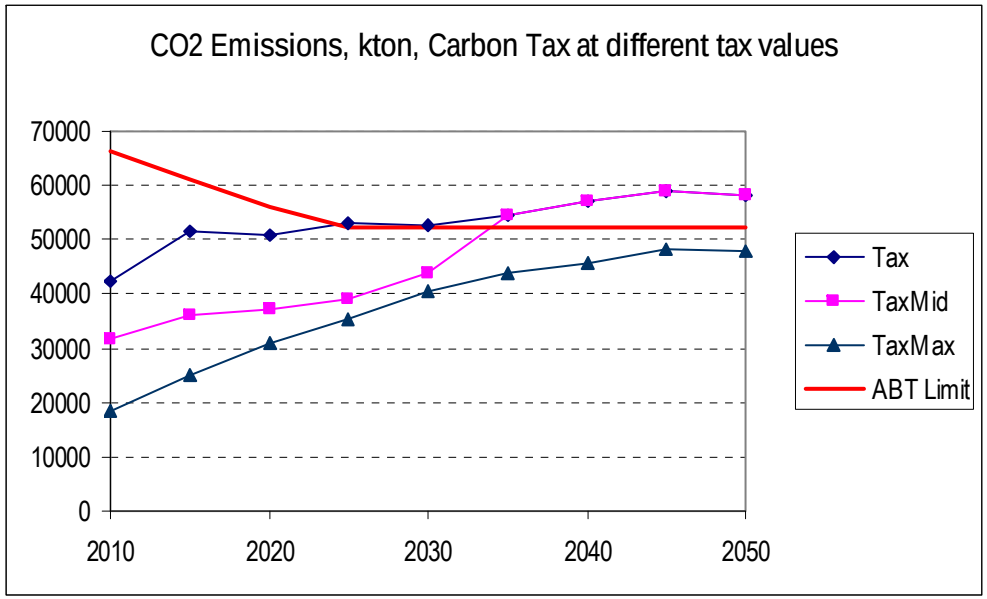
- Energy mix is varying depending on the imposed CO2 limits, and on the prices of CO2 emissions, or level of price cap or taxes.

Results CO2 Emissions



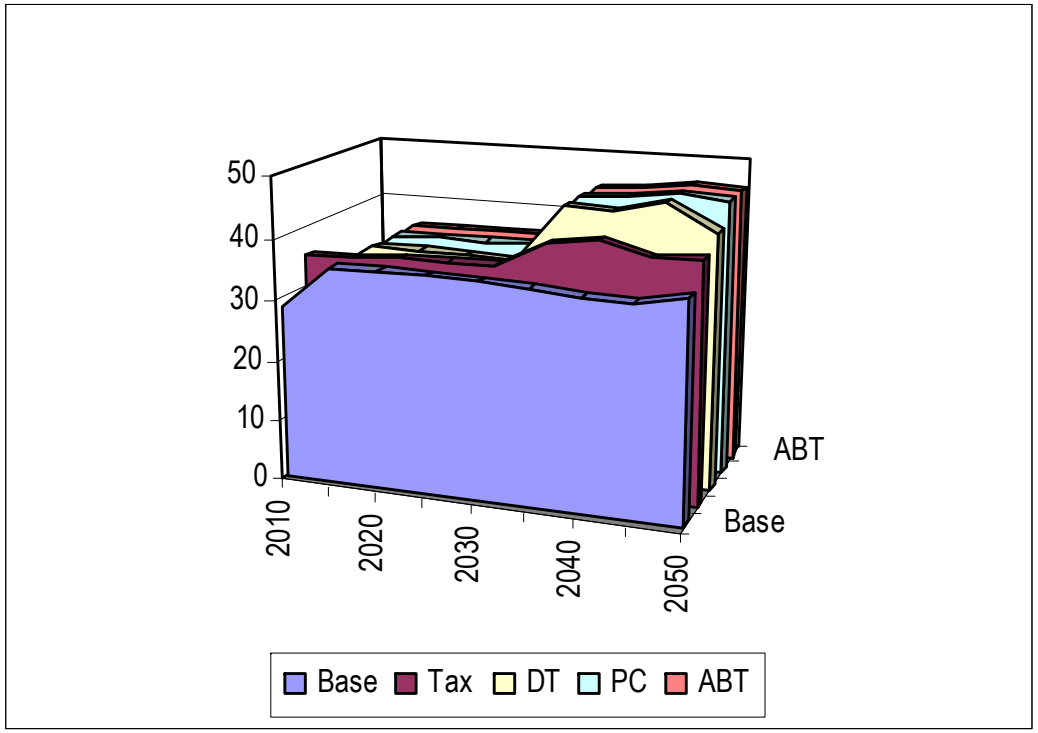

CO2 Emissions, kton, ABT at different emission prices
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
2010
2020
2030
2040
2050
ABTLow
ABT
ABTHigh
ABT Limit


CO2 Emissions, kton, Price cup at different cap values
70000
65000
60000
55000
50000
45000
40000
35000
30000
2010
2020
2030
2040
2050
PC
PCLow
PCHigh
ABT Limit


CO2 Emissions, kton, Carbon Tax at different tax values
70000
60000
50000
40000
30000
20000
10000
0
2010
2020
2030
2040
2050
Tax
TaxMid
TaxMax
ABT Limit

- Results in respect to the achievement of environmental target vary depending on the emission limits and prices.

Results Shadow Price of Electricity



Impact of different approaches

- If there are no CO2 limits imposed, the energy sector will follow the least cost approach, developing the available sources first by cost, then depending on their restrictions in respect to availability and other environmental restrictions (SO2).
- If CO2 limits are imposed, the price of carbon emissions or price of carbon taxes will have significant effect on the energy sector development, in two directions – resource profile and cost of energy / electricity.

Impact on resource profile

- Generally it is expected that, besides the energy saving measures, there will be a movement to the more environmental-friendly resources. The resource profile may change toward the larger application of gas and nuclear in replacement of lignite coal. However, due to the very low price of local lignite sources, their importance for the country economy will remain significant. It should be noted also that current study does not consider option for future development of coal power plants with carbon capture facilities. This could be one of the possible alternatives for the country, if suitable places for CO2 storage are found.
- Higher emission prices, or price cups, or tax values will result to higher decrease of coal resources, and respectively will lead to higher shares of gas and nuclear. And in the opposite, lower emission prices, or price cups, or tax values will lead to lower decrease of coal resources.

Impact on cost of electricity

- Achievement of environmental goals will definitely increase the economic burden of society, and in particular will impact the cost of electricity.
- Based on the considered scenarios in the case study, environmental goal 20% reduction of CO2 emissions by 2020 applying emission trading approaches (ABT, DT or PC) at middle prices of 30 euro per ton CO2 will not impact significantly the cost of electricity in the country up to 2020. But further 30% reduction of emissions by 2030, combined with closure of existing nuclear units, will lead to about 30% increase of the average cost of electricity.
- Carbon tax approach at assumed tax value of 10 euro/ton will impact the electricity cost by about ~ 5% in the period up to 2030, and by ~ 15% after 2030 (latest due to closure of existing nuclear units).
- Higher emission prices, or price cups, or tax values will result to higher impact on the costs of electricity. And in the opposite, lower emission prices, or price cups, or tax values will lead to lower impact on the costs of electricity.

Impact on CO2 emissions

- Environmental goal in general is defined as 20% reduction by 2020 and 30% reduction by 2030 of CO2 emission levels at base year 1988.
- In the Base case, where CO2 limits are not imposed, the emissions are forecasted to exceed the defined limits after 2020 (2018-2019).
- For scenarios with imposed limits (ABT, DT, PC), the defined limits are not exceeded in general at assumed middle prices of emissions or price cup of 30 euro/ton. At lower prices of emissions (10 euro/ton) or lower price cup (20 euro/ton) the defined limits might be exceeded after 2030 - 2035.
- Carbon tax scenario does not include limits, and at assumed tax of 10 euro/ton the defined limit is exceeded after 2025. This could lead to a conclusion, that the selected base tax value might not be sufficient to achieve the environmental goals. Some higher tax value of 20 euro/ton does not change too much the environmental results in long term perspective, while decrease significantly the emissions during the first half of the considered period. In case of high tax value of 30 euro/ton, the environmental goal could be achieved in long term perspective as well. However, tax value shall be considered with special caution to the economic impact.

Comparison of approaches (1)

- Emission Trading versus Carbon Taxes
  - Emission Trading allows application of market principles in achievement of environmental goals, but makes the economic environment less predictive.
  - Tax approach might combine administrative and market principles and might provide more predictable investment environment, but will require strong management arrangements.

Comparison of approaches (2)

- Absolute Binding Target versus Flexible Targets
  - At the same carbon prices, Dual Target approach could be attractive if the lower emission limit is close to the ABT limit and the upper emission limit is higher than ABT. Otherwise, if free emission quotas are available to sell, the dual target approach may restrict these opportunities and Dual Target approach could not be attractive.
  - Flexible targets, in both considered variants of dual target and price cup, may provide some advantages while protecting against unpredictable and / or high economic burden, therefore could be more appropriate for developing or for less-developed countries. However, these approaches shall be applied with caution in respect to achievement of environmental goals.

Comparison of approaches (3)

- Carbon tax levels
  - The selected base tax value of 10 euro/ton might not be sufficient to achieve the environmental goals in long term perspective. Higher tax values, while providing better results in respect to the emissions, might impose significant economic burden. A possible option for future consideration, if carbon tax approach is preferred, could be variable taxes in time – low taxes currently, increased in the future depending on the achievements and needs in relations to GHG reduction.

SWOT ABT

- Strengths:
  - provide market mechanism to avoid emissions
- Weaknesses:
  - subjective in the first steps and control
  - requires significant efforts to establish fair system for emissions accounting and allocation of allowances
  - very dependent on the level of emission allowances (example experience during the first years of ET scheme in EU 2006-2007).
- Opportunities:
  - introduce market principles in emission reduction
- Threats:
  - if the allowances are very large, may not lead to necessary goals
  - if the allowances are very strength, may overburden the economies and to compromise market principles.

SWOT Carbon Tax

- Strengths:
  - provide to the state direct leverage to control emissions, combining market and administrative measures. However, market measures are restricted.
  - Long term investments need predictability, that could be provided by tax system and not by ET.
- Weaknesses:
  - needs to establish effective system for management of tax fund.
  - market measures are restricted
  - very dependent on the level of taxes
- Opportunities:
  - introduce combination of administrative and market principles in emission reduction
- Threats:
  - if the taxes are very low, may not lead to necessary goals
  - if the taxes are very high, may overburden the economies and to compromise market principles
  - if the fund is not spend for clean development, or spent inefficiently, may compromise the entire scheme. Clean development may include technologies for CO2 capture and storage, for energy efficiency, for new combustion technologies. Then probably we shall not speak about installations, but about system for power production.

SWOT Dual Target

- Strengths:
  - Similar to ABT provide market mechanism to avoid emissions;
  - In contrast to ABT Dual intensity targets for middle-income countries could address concerns that emission targets might threaten economic development, while avoiding the risk of hot air.
- Weaknesses:
  - Weaknesses of ABT approach remain;
  - Effectiveness in achieving environmental goals will strongly depend on the level of emission allowances
  - Market mechanisms could also be compromised by the distribution of goals between the countries as a whole, and between subjects in the country.
  - Subjective in the first steps and control;
  - Requires significant efforts to establish equitable system for emissions accounting and allocation of allowances;
  - More difficult to apply in regard to the ABT.
- Opportunities:
  - Introduce market principles in emission reduction, while providing some compromises for less developed countries.
- Threats:
  - if the upper allowances are very high and / or bottom allowances are very low, may not lead to necessary goals
  - if the upper allowances are very strength and / or bottom allowances are very high , may overburden the economies and to compromise market principles

SWOT Price Cap

- Strengths:
  - Similar to ABT provide market mechanism to avoid emissions;
  - In contrast to ABT, price cap will limit the economic burden in case of significantly high emission prices. The latest may happen on the market in case there will be a deficiency in free emissions.
- Weaknesses:
  - Weaknesses of ABT approach remain;
  - A new weakness is however added related to the determination of price cup.
- Opportunities:
  - introduce market principles in emission reduction, while providing some protection in case of significant increase of market price of emissions.
- Threats:
  - related to the determination of allowances – like for ABT approach;
  - related to price cap – if the price cap is very high, the protective function might be compromised and in the opposite – if the price cap is very low, this may disturb achievement of environmental goals.

End