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THE EXPECTED IMPACT OF THE INTRODUCTION OF CARBON-DIOXIDE TRADING ON THE DOMESTIC POWER MARKET

This study forms part of the research project entitled 'Directive introducing the carbon-dioxide trading scheme of the EU, tasks relating to adoption and the expected budgetary impacts'.

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This paper reflects the views of the authors and
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Summary

This paper studies the impacts of introducing the regulation of carbon-dioxide emission trading in the power market. The main point of regulation is to turn carbon-dioxide emissions into a tradable commodity, as a way of encouraging enterprises to reduce their emission levels. A number of different scenarios covering the development of market conditions will be outlined and examined, basically for two types of effects: the change in power market prices, and the expected state revenue.

The supply of power will be described by a stepped curve that expresses both the different operating costs of the various generating capacities, and their output capacities. Demand comprises a liberalised and a captive segment. The prices in the latter segment are regulated by decrees. The impact of the regulation of emission trading on the power market can be reviewed through alteration of the supply curve.

According to the model, the enterprises decide on the amounts they will invest in reducing their emissions and on the proportion of their emission permits (allowances) to be sold, taking account of the expected cost of a unit reduction in their own carbon-dioxide emissions (marginal abatement cost), the market price of electricity, and the price of the pollution permit (allowance). A dozen versions of the model are produced on the basis of such external factors as the European CO_2 allowance price, the import power price and the natural gas price and how they develop.

The regulation specified in the National Allocation Plan of 8 October 2004 – which includes auctioning 2.5% of the allowances – is assessed in the model. The price of electricity increases substantially as a consequence of regulation only if the allowance price exceeds €10/t. A high allowance price would result in prices on the domestic power market being 3–6% higher than they would be without regulation. At the same time, in each model version the carbon-dioxide emissions of domestic enterprises are substantially lower in 2010 than the level expected without regulation.

The revenue accruing to the state from auctioning the quotas would be between HUF 0.3 billion and HUF 1.0 billion in the group of power plants under review during the period between 2005 and 2007, if the allowance price falls between €3 and €10/t. The budget could earn an additional HUF 2–11 billion per year by auctioning the part of the quantity of allowances that, under the existing allocation plan, would be distributed free of charge over and above current actual emissions (the over-allocated part).

Introduction

This study presents an analysis of the effects of the carbon-dioxide emission trading regulation introduced under European Union directive No. 87/2003/EC, on the domestic power market. Our assessment of the effects on the power market covers both the change in the position of the power generators, and the effects as perceived by electricity consumers.

The first section of this paper contains a description of the model we have developed to explore the issue. To analyse the impact of CO_2 regulation we have carried out a series of calculations in a static partial equilibrium model. One set of calculations explored the relationships between supply and demand in the power market, and another assessed the effects of CO_2 regulation.

The second section of the study presents twelve different scenarios based on different values assigned to the market and the regulatory model variables we regard as important, as well as a discussion of the observed effects on the power market, comparing these to the basic models without CO_2 regulation.

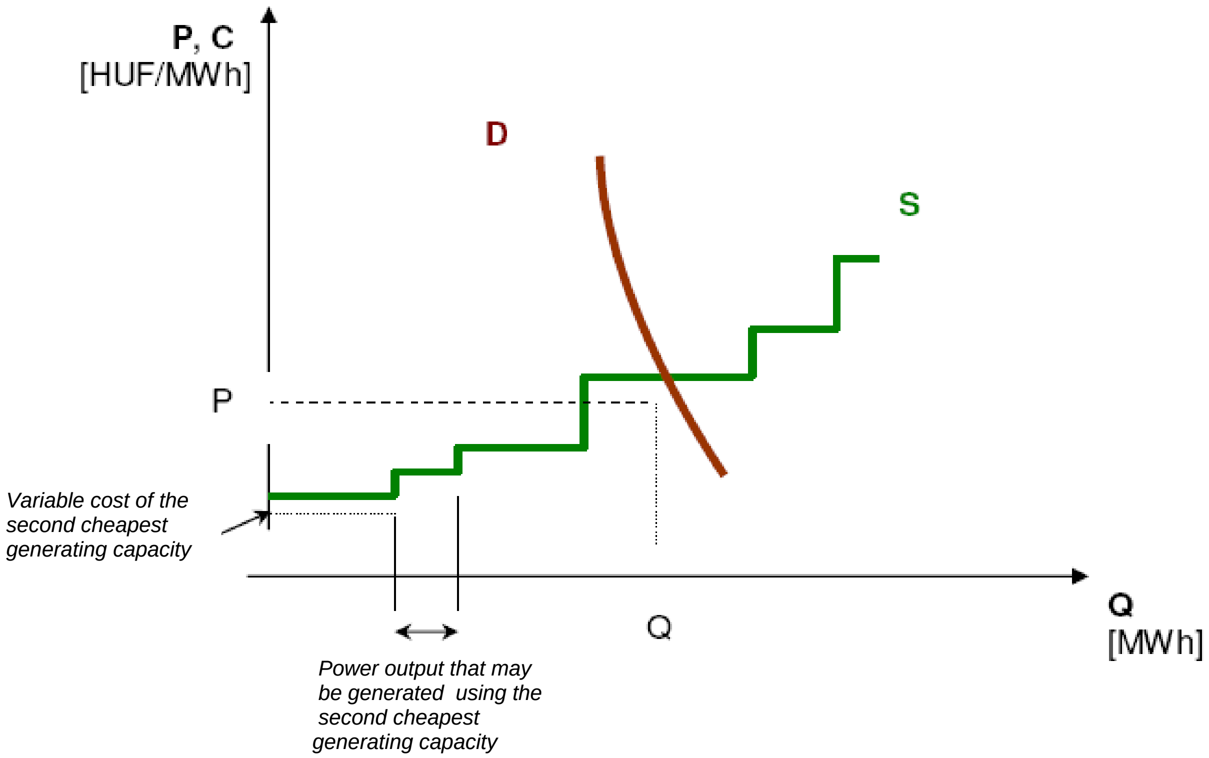
This study is closely related to the paper entitled 'Theoretical foundations and EU regulation of carbon-dioxide emission trading' published in March 2005 as the 11th Working Papers of the Hungarian Ministry of Finance. Therefore, this study will not contain any discussion of the theoretical foundations underlying our calculations, since these are detailed in our previous paper.

1. Description of the model

1.1 Assessment of the operation of the power market

The operation of the electricity market can be modelled on the basis of the so-called load distribution algorithm, in which the operator of the power system loads the production capacities (which generate power for the network) available in the power network in an order that corresponds to the changing operating costs of the various production capacities, to cover the demand for power at any given point in time. Supply in the power market may be described in a simplified way using a stepped curve, where the various steps are determined by the output capabilities of the various generating capacities and the variable costs of their operation (Bach, P. F. (2003), Paul, A. and D. Burtraw (2002), North, M. *et al.* (2002), Hogan, W. W. (1993)). The stepped supply curve is based on an assumption that the various power generator sets are capable of generating power at constant variable costs across the whole interval of their capacity.[1] The in-built capacity of a power plant determines the maximum possible output, while the variable cost per kWh that is characteristic of any given power plant unit can be calculated on the basis of the technology of the generator set, its technical features and fuel consumption (or efficiency). The following figure shows the relationships between supply and demand in the power market.

Figure 1. Trend of market equilibrium in the case of a stepped supply curve



The so-called 'merit order dispatch' scheme places the production units in its schedule according to their variable costs to ensure the demand for power is met at any point in time, i.e. it is assumed that the market will always choose the least expensive capacity available. The variable cost of the last power generator set still involved in meeting demand determines the free-market price.

[1] Though it is not entirely true that the cost of generation does not change with output, since, using the power plant characteristics curves that describe the heat consumption characteristics as a function of the load on the unit, it is possible to identify an optimum load for each set, where the unit operates at the lowest unit heat consumption (Balogh and Bihari, 2002). At the level of abstraction required for modelling, however, the assumption of a constant average variable cost that corresponds to the marginal cost is sufficiently close to reality.

Under the 2001 legislation on electricity (Act No. 2001/CX), 1 January 2003 saw the start of the liberalisation of the power market, which had hitherto been operating exclusively in the form of a captive system of power supply. Liberalisation of the power industry is to proceed gradually, and until 2007 at least there will be two markets operating under different conditions – the captive segment and the liberalised power market. Accordingly, during the period under review, demand will be made up of a captive segment and a free-market segment. In our calculations, and in line with the trends observed over recent years, liberalisation of the market proceeds rather more slowly than under the scenario of market liberalisation outlined in EU Directive 2003/54/EC. Our calculations are based on the following schedule of market liberalisation:

Table 1. Size of the free-market segment

Year	Proportion of consumption in the free market
2002	0%
2003	18%
2004	22%
2005	25%
2006	30%
2007	35%
2008	40%
2009	50%
2010	60%
2011	75%

Source: authors' estimate.

Demand in the captive sector is determined on the basis of projections, and the prices applied are the regulated tariffs published in the decrees issued by the Ministry of Economic Affairs from time to time, separately for the various industrial and household consumer groups (Power Act No. 2001/CX). In 2003 GKI (Economic Research Institute) was commissioned by MAVIR (Hungarian Power System Operator Company) to produce a power demand projection (MAVIR, 2003) to be used in the medium and long-term capacity planning for the Hungarian electricity system. Data from the projection are used in our modelling exercise to predict the growth in demand in the captive segment. According to the GKI projection for MAVIR, the peak load on the power system will increase by an average of 1.8% per year over the next decade. Accordingly, a 1.8% rate of growth in the demand for power in the captive segment is used in our calculations.

Exponential demand curves were used to predict demand for power in the free market. This made it possible to take into account the price sensitivity of consumers, too, in the free-market segment. A short- and medium-term feature of the power market is its low degree of demand–price flexibility. In view of the lack of relevant Hungarian predictions, the price flexibility data required to establish free-market demand were estimated on the basis of international technical literature.[2] As for the demand–price flexibility of household consumers in the power market, we used data provided by the social research institute TÁRKI (2003). For industrial consumers and for household consumers we assumed a -0.25 and a -0.15 price flexibility factor, respectively. The demand for power at any given point in time equals the sum of the captive and free-market demand established for that point in time.

Demand in the captive market is met by capacities committed to the captive regime up to an amount set for any given year.[3] The gradual growth of the free market is accompanied by a corresponding shrinking of the captive market, and the captive capacities that are not loaded in the public utility operations, as well as the capacities without long-term contracts, are involved in the free-market load distribution in an increasing order according to their variable costs.

The effects of CO_2 regulation on the power market can be assessed from the way the supply curve shifts. Since the inverse power market supply curve is determined by the amount of power, which in turn is determined by the unit cost of generation and the capacities available at the various power plants, the changes in these values that result from the introduction of regulation need to be analysed in order to explore the effects of CO_2 trading on the power market.

1.2 Corporate decisions relating to carbon-dioxide regulation

Since the goal of the EU regulation aimed at reducing the emission of greenhouse gases is to stimulate enterprises into reducing their emissions, our calculation model is based on the assumption that enterprises participating in emission trading will decide on the possibilities of investment projects relating to abatement and/or on the sale or purchase of emission permits, based on their own marginal abatement cost (MAC) curves and the power price and CO_2 allowance price (both factors determined externally).

In order to model the decisions to be made by companies, we looked at the abatement options available to the operators of the various initial power plant technologies. Using the unit CO_2 emission ratios, emission reduction potentials and investment costs of the various power plant technologies, we summed up the technological options that entailed CO_2 reduction. On the basis of this we can observe the unit cost increases needed to reduce the CO_2 emission levels of the various power plant technologies to various specific levels.

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[2] Donnelly, W. A. (1987) *The Econometrics of Energy Demand : a survey of applications*, Praeger, New York.

[3] The amount of capacity committed to public utility purposes was estimated on the basis of Horváth (2004), in BKAE, Rekk (2004).

In identifying the abatement options, we considered the following three possible ways of reducing greenhouse gases (GHG) that are available to fossil fuel generators: 1) efficiency improvement; 2) change of fuel; 3) end-of-pipe abatement.[4] Our model involves a variety of abatement options for power plants that use different fuels and different generation technologies. A solution from among the abatement options contained within the model may be achieved by altering the parameters in the model to take account of the individual features of each power plant involved in our analysis.

In the case of coal-burning power plants the following abatement options are contained within our model: a) simple pulverised coal combustion (PCC – the basic set-up); b) atmospheric fluidised bed combustion (AFBC); c) pressurised fluid bed combustion (PFBC), d) a technology that gasifies solid fuel and then uses it for combined gas and steam cycle power generation, that is Integrated Gasification Gas Combined Cycles (IGCC). The use of e) a high surface area heat exchanger that offers an improvement in the recovery of the caloric energy of the flue gas was included as an abatement technique that does not necessitate any change in the basic technology, along with f) pre-drying of the coal using a fluid bed heated using a steam-heated piping system. Switching the fuel offers two more options: introduction of biomass or natural gas-based combustion. Various solid fuel combustion techniques are available if biomass is used. If the plant switches to natural gas, then a complete technology change is possible even with the use of a simple steam cycle system: investment in open or combined cycle gas turbine technology is among the available options.

In the case of hydrocarbon-burning power plants, CO_2 emissions may be reduced by altering the relative proportions of fuel oil and natural gas, or by introducing gas turbine technology (open or combined cycle) in place of the steam cycle.

After assessing a number of options (CO_2 absorption by membrane, chemical or physical overcooling) we decided to take into account only the end-of-pipe technology with the lowest unit cost. This is the MEA scrubber, based on the technique of spraying monoethanolamine into the flue gas and then mechanically separating the precipitation formed with the CO_2. Each end-of-pipe technology entails an increase in the consumption of energy for the operation of the power plant and a consequent deterioration in the overall efficiency of operation, resulting in a significant increase in the total cost of power output.

It is assumed that power plants decide on the various alternative options for investment on the basis of the discounted cash flow over the life cycle of a given

[4] The sources of the abatement marginal cost curves we built up include the power plant technology descriptions and cost data published in international technical literature, along with the CO_2 database of IIASA, which contains the investment and operation parameters of operational and experimental power plants that utilise the various available technologies, along with the associated costs. A complete list of the sources is presented at the end of this study.

technology based on an estimated CO_2 allowance and an estimated electricity price (also taking account of the expenditure and revenue relating to CO_2 regulation). To calculate cash flows, the future cash movements on the revenue and the expenditure sides were identified in relation to each technological step, for one kW of output. The items on the expenditure side included the one-off specific investment cost incurred in the first year, the fixed and the various operating and maintenance costs, the fuel costs and the cost of allowance purchase, if any. The revenue may come from the planned sale of power and from the sale of allowance, if any.

Modelling is based on real values, net of the effects of inflation. The external factors of the European power sale price and the CO_2 allowance price in the period concerned may be specified in order to calculate revenue and costs. The algorithm chosen for our analyses uses the power output (in kW) that corresponds to the pre-estimated capacity actually available for a given technology. The power plants make their choice from the available options before the period of regulation, but after CO_2 regulation comes into force. The model takes account of the unit costs and capacity utilisation rates characteristic of the new technology, from the year the investment project concerned is completed.

The enterprises' own fuel composition[5] is used as input data, from which the model calculates the CO_2 emissions using the emission factors determined by the IPCC.[6] The quantity so allocated, and the principle of allocation, can be freely defined in the model. The calculated necessary output quantity can also be freely restricted and the auctioned percentage may also be freely set. Besides auctioning, an emission- or output-based allocation mechanism may be chosen. As will be described in detail below, in the course of our calculations we built the latest effective allocation data of the Hungarian National Allocation Plan into the model.

On the basis of the technology parameters applied, together with a given CO_2 price and the mode of allocation, it is possible to calculate whether each and every power plant will have a surplus or a shortfall of allowance in a given year. The value of the calculated allowance surplus/deficit (expressed in HUF) is added to the unit cost of generation and will alter the shape of the supply curve. The various technological options may influence even the amount of the available capacity. The available capacity and variable cost data that characterise the stepped supply curve of power generators are modified in our model, depending on the technologies chosen by the various generators and the allowance price. By seeking and identifying the new equilibrium price in the market, we identify the power price and consumption data that are characteristic of a given assessment scenario. The development of equilibrium in the market is shown in the following figure. The values C_1 and C_2 and Q_1, Q_2, as well as C'_1 and C'_2 and Q'_1, Q'_2 show the unit costs of

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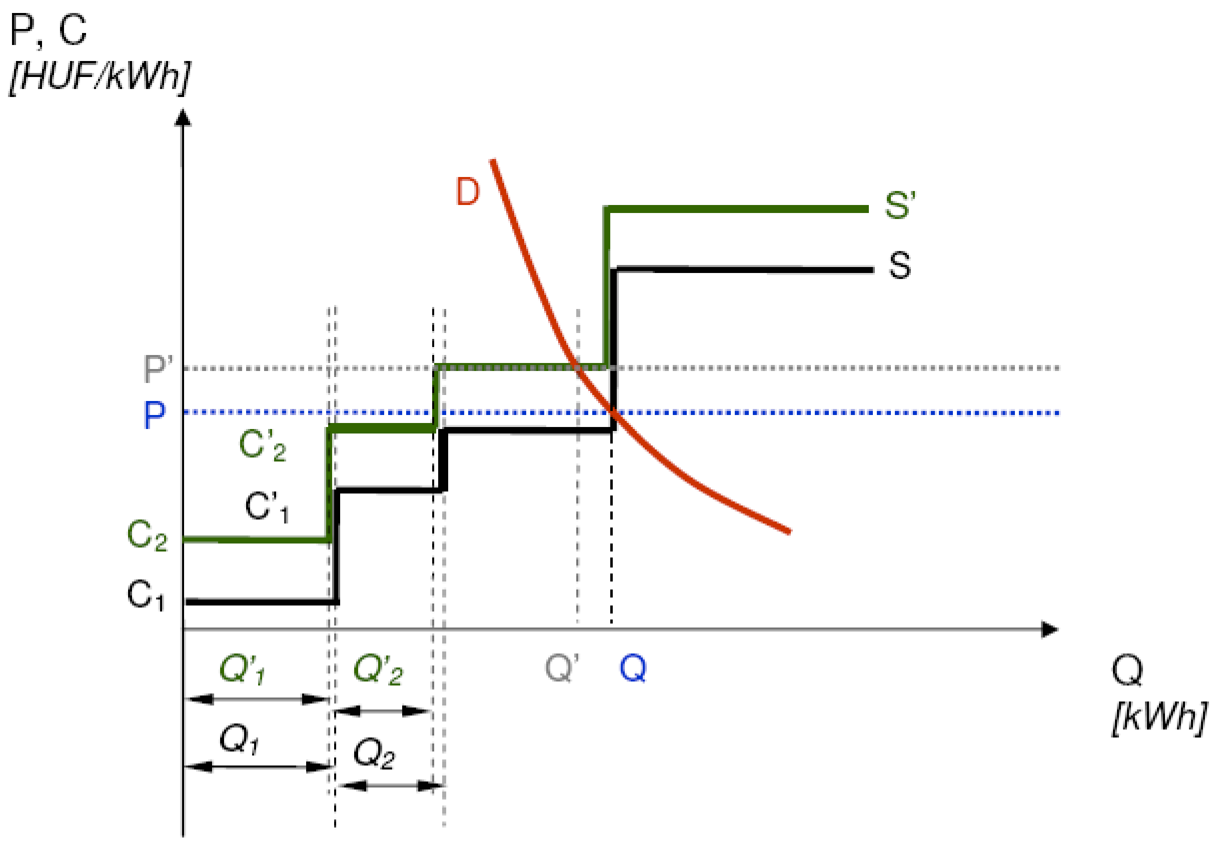
[5] MEH [Hungarian Energy Office] (2002) *Villamos energia statisztikai évkönyv* [*Electricity statistics year book*], 2002.

[6] IPCC: Intergovernmental Panel on Climate Change: *Good Practice Guide and Uncertainty Management in National Greenhouse Gas Inventory* , http://www.ipcc-nggip.iges.or.jp/public/gp/pdf/2_Energy.pdf

the two least expensive power generator sets and their output (kWh) with and without the introduction of regulation.

Figure 2. Change of the equilibrium in the market as a result of CO_2 regulation



1.3 The basic settings of the input data for our calculations

The following exogenous variables were set in the model:

- **European CO_2 allowance price**: The data presented above are based on allowance prices of €3, €5 and €10.
- **Import price of electricity**: The European price of power and the sale price of imported power used in our calculations for investments is €30 per MWh, which was a typical benchmark price on the EEX (European energy exchange)

in 2004. In order to take account of the potential price-driving effect of CO_2 trading, the futures benchmark prices were taken into account:[7]

Table 2. The futures European power price (benchmark) taken into account in the calculations

	2005	2006	2007	2008	2009	2010
EUR/kWh	0.0345	0.0348	0.0354	0.0377	0.0385	0.0394
HUF/kWh	8.65	8.73	8.88	9.45	9.65	9.88

- **Change in the price of natural gas**: As a consequence of CO_2 regulation the proportion of gas-fired power generation will probably increase at the expense of coal- fired technologies, among both Hungarian and broader European power plants. No reliable estimate is available on the change in the price of gas. According to some experts, the gas price increase resulting from carbon regulation may be partially offset by a gas price reduction that is anticipated in the wake of the future liberalisation of the gas markets across Europe. The model allows a percentage rate of gas price increase to be set, which will have an effect both on the choice of abatement technology and the unit cost of generation at gas-fired power plants. In this assessment we used a 0% and a 15% gas price increase.

- **Discount factor**: The discount rate required for calculations concerning investments is set at 10% in our model, on the assumption that this is the discount rate at which investors expect their investments to pay off during the life cycle of the technology.

Additional important comments:

- Other Hungarian power plants include smaller-capacity units of combined power and heat generation, along with capacities that use renewable fuels and fall within the scope of compulsory power purchase according to Decree No. 56/2002 GKM of the Ministry of Economic Affairs.

- Guaranteed purchase is assumed for the power output that corresponds to the actual available capacity of the Oroszlány power plant (126 MW).

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[7] The European power prices are based on price data of the Frankfurt EEX concerning current benchmark and futures transactions (2005–2010).

www.eex.de/futures_market/market_data/intraday_table_print_e.asp?type=2004.08.02 (date of query: 02 August 2004, 14:20).

- The capacity of units I and II of the Mátra power plant fixed by MVM Partners is considered as contracted capacity for the period 2005–2010.

- The contracted import capacities of MVM (ATEL, EGL, SYSTEM) are given priority in load distribution.

- To ensure comparability of annual results, the available capacity of the units of the nuclear power plant at Paks was set as 'fully available' in both 2003 and 2004.

1.4 National Allocation Plan

There are currently two known versions of the National Allocation Plan, and at the time both of writing and of drawing up the modelling scenarios the Hungarian government's proposal for the initial allocation of CO_2 emission allowances according to the EU Emission Trading Scheme (ETS) had not been finalised. The first version of the National Allocation Plan was published on 20 September 2004, and the second version was dated 8 October. The National Allocation Plan contains sectoral total allowance quantities, along with quantities of allowances at facility level, to be allocated free of charge. The power plants covered by our study are licensable power generators, and accordingly the individual emission allowance quantities pertaining to such generators are listed in sector 'I/a' of the National Allocation Plan for years 2005, 2006 and 2007. (Sector I/a constitutes the licensable generators in the scheme of the Hungarian Energy Office.)

Besides the free individual emission allowances, the National Allocation Plan also provides for allowance quantities to be auctioned in each branch. In the version dated 20 September the figure for this was 1%, while in the 8 October version of the National Allocation Plan it was 2.5%.

The following table presents a summary of the quantities of allowances that may be allocated free of charge to power plants covered by our model, as detailed in the two versions of the National Allocation Plan (NAP). There is obviously little difference between the quantities of the total allowances in the two versions, but there is a rearrangement in the allocation of the allowances.

Table 3. The CO_2 allowances that may be allocated free of charge under the National Allocation Plan to power plants covered by this study (in tonnes)

	20 September		**8 October**	
	2005-6-7 each year	**over three years total**	**2005-6-7 each year**	**over three years total**
Bánhida	94 126	282 378	93 706	281 118
Oroszlány	1 309 329	3 927 987	1 303 487	3 910 461
Dunam. II	1 401 796	4 205 388	1 395 541	4 186 623

Dunam. GT1	658 958	1 976 874	677 011	2 031 033
Dunam. GT2	683 422	2 050 266	702 144	2 106 432
Mátra I-V	6 419 736	19 259 208	6 229 697	18 689 091
Tisza II	1 526 109	4 578 327	1 519 300	4 557 900
Tiszap. I-III	532 797	1 598 391	530 420	1 591 260
Csepel GT	846 767	2 540 301	869 965	2 609 895
Pécs IV-V	260 787	782 361	351 246	1 053 738
Újpest+Kispest	622 748	1 868 244	639 808	1 919 424
Kelenföld GT	296 625	889 875	304 751	914 253
Debrecen GT	313 294	939 882	321 877	965 631
total	14 966 494	44 899 482	14 938 953	44 816 859
other power plants	540 515	1 621 545	917 319	2 751 957
altogether	**15 572 224**	**46 716 672**	**15 856 272**	**47 568 816**

Notes:

Other power plants include: AES Borsodi Energetikai Kft – Kazincbarcikai Erőmű fossil fuel units; Bakonyi Erőmű Rt – Ajkai Erőmű; Budapesti Erőmű Rt – Kőbányai Erőmű; the power plant of EMA-Power Rt; G-TER – Litér, Lőrinci, Sajószöged power plants and, according to the 20 September version, Bakonyi Erőmű Rt – Inotai Erőmű; and Vértesi Erőmű Rt – Tatabányai Erőmű.

The total power output of the power plants covered by our calculations also includes the power output of small power plants produced as cogeneration and bought up under the compulsory purchase arrangement. This group of power plants is included in our calculations only in aggregate, for they are not included among the licensable generators in the scheme of the Hungarian Energy Office, and accordingly, instead of sector I/a of the NAP, they are included in sectors I/b or I/c.

Other power plants and heating facilities that generate power in combination with caloric energy for heating (steam and hot water supply) in a district are listed in sector I/b of the NAP, rather than I/a sector. Combustion facilities whose output is consumed by their operators are listed in sector I/c.

Our model calculations were carried out using the free individual power plant emission caps and an auctioned proportion of 2.5%, as specified in the 8 October 2004 version of the NAP. Accordingly, we can also present the effects of the latest version of the National Allocation Plan. To assess these regulatory arrangements we developed 10 different model versions by altering the parameters of three important variables within the model. These three model variables are: the average end-user price of natural gas, the average import price of power, and the average market price of CO_2 emission allowance.

Natural gas plays a major role in power generation in Hungary: as a fossil fuel it is practically equal in importance to coal. It is expected to grow in importance, not only as power plants switch fuels, but also in view of the choice of fuel of capacities yet to be built. While the types of coal used in power generation in Hungary are raw materials that originate from integrated individual mines owned by the generators, natural gas is a product purchased on the market and is thus more exposed to market influences. Two versions were applied with respect to the end-user price of natural gas. One assumes the maintenance of the existing price level in real terms, while the other assumes a natural gas price level some 15% above the price level during the period under review.[8]

As a result of the gradual liberalisation of the power market, imported electricity will play an increasing role in domestic supply and, consequently, in the development of power prices in Hungary. As was outlined above, two power import price scenarios were used in our model calculations. The difference between them is that one assumed no change in the price of imported power, while the other assumed an increasing import price.

For the market price of CO_2 emission allowances we used three parameter values. The third quarter of 2004 was characterised primarily by a small volume of forward transactions on the European carbon market, with typical contract prices of around €8/t.[9] Therefore, our results are examined on the basis of an allowance price of €5 and €10/t. However, according to the national allocation plans submitted to the European Commission and the responses of the Commission so far, demand is expected to be lower than originally expected, since the majority of the national governments did not apply strict basic principles to establish the total quantities to be allocated.[10] For this reason, our results will also be assessed on the basis of a much lower than expected allowance price of €3/t CO_2.

By altering the parameter values of the different versions of the model, a total of twelve different model versions were developed. Accordingly, a total of fourteen different model versions have been compiled in this study, including the basic scenarios pertaining to the 'business as usual' (BAU; gaz0BAU; gaz15BAU) scenarios

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[8] The expectations concerning the domestic price of natural gas vary widely according to the weights assigned to the various conditions and the expected extent of their changes. Natural gas is not a mass commodity in the traditional commodity exchange meaning of the term, and therefore its price may vary widely in a given region, depending on the agreements between the enterprises involved in production, transport and distribution, as well as between traders and groups of consumers. At present, the price level in the domestic category of large consumers is similar to the average large consumer price level prevailing in the EU, and both effects that depress and effects that increase the prices are expected to influence the development of the gas price. The consistently high oil price may drive a price increase, while deregulation of the natural gas market may reduce prices, since the gradual liberalisation of the market may result in more favourable terms than those offered by the captive market supply contracts for a significant percentage of large consumers as well.

[9] Data on individual transactions and aggregate market information: www.pointcarbon.com; regular downloads.

[10] The national allocation plans submitted by the member states and the versions accepted by the Commission are accessible on the home page of the EU Environment Directorate General. Downloads: October 2004; http://europa.eu.int/comm/environment/climat/emission_plans.htm

without CO_2 regulation.[11] The following table provides an overview of the model versions assessed in our study.

Table 4. The variables modified in the course of modelling, and their parameters, the model versions so assessed and the titles of the various scenarios in the study

		Average import power price			
		fixed current real price		according to futures contract prices on the power exchange	
		Change in natural gas price level		Change in natural gas price level	
		0%	+ 15%	0%	+ 15%
CO_2 allowance market price, €/t	3	**3€-gaz0imall**	**3€-gaz15imall**	**3€-gaz0imfut**	**3€-gaz15imfut**
	5	**5€-gaz0imall**	**5€-gaz15imall**	**5€-gaz0imfut**	**5€-gaz15imfut**
	10	**10€-gaz0imall**	**10€-gaz15imall**	**10€-gaz0imfut**	**10€-gaz15imfut**

The following is an overview of the results of the various modelling scenarios.

2. The results of modelling

2.1 Models based on unchanged gas prices

Leaving aside the case without CO_2 regulation, these models show that the way the price of imported power develops will have a greater impact on marginal costs in the domestic free-market power system than the introduction of CO_2 emission trading. If the power price remains stable in Europe despite the introduction of CO_2 trading by the European Union (in the case of an allowance price of €3 or €5/t this is a realistic assumption, particularly in view of the substantial imports from non-EU member states such as the Ukraine and Romania), then the marginal costs of the power system will not change substantially in comparison to the marginal costs without the introduction of CO_2 regulation. A free-market price slightly higher than the BAU will develop only in the case of an allowance price of €10/t, which – assuming that import prices remain unchanged – will mean that the €10/t CO_2 cost to domestic generators will increase the costs of a marginal generator. If the price of power available from imports does remain stable, this could be a result of the effect of the dominant role of CO_2-neutral nuclear energy or of deregulation in Europe. The increasing liberalisation of the market, however, means that the import

[11] The import price of electricity is set as 'fixed at the current price level' in the models without regulation (BAU), i.e. there is no BAU version with increasing power price, for any growth in power prices is associated with the introduction of CO_2 regulation at the European Union level.

capacities will not cover the increased demand for free-market capacities, and as a consequence the domestic price at an allowance cost of €10 will diverge from the BAU, the €3 and the €5 versions.

If, however, despite the unchanged gas prices the introduction of CO_2 regulation in Europe is accompanied by a growth in imported power prices by a percentage that is taken into account now in futures transactions, the domestic free-market price will significantly exceed the price without CO_2 regulation, since the price of power available from imports will also be higher and, as a result of the higher import price, power plants that generate electricity at higher costs will also come to be involved in Hungarian power generation.

Table 5. The development of the free-market price of power in the case of different CO_2 allowance prices, unchanged gas price, unchanged and growing import power prices, HUF/kWh

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
BAU	7.68	7.70	7.85	7.90	8.13	8.45	8.88	9.52	10.02	10.33
In the case of unchanged import power price										
€3/t CO2	7.68	7.70	7.85	7.92	8.20	8.52	9.00	9.52	10.07	10.36
€5/t CO2	7.68	7.70	7.85	7.92	8.20	8.55	9.04	9.53	10.05	10.37
€10/t CO2	7.68	7.70	7.88	8.08	8.39	9.02	9.57	10.01	10.37	10.69
In the case of growing import power price										
€3/t CO2	7.68	7.70	8.74	8.76	9.00	9.57	9.79	10.07	10.19	10.39
€5/t CO2	7.68	7.70	8.74	8.76	9.00	9.57	9.79	10.07	10.19	10.39
€10/t CO2	7.68	7.70	8.77	8.87	9.11	9.66	9.93	10.24	10.48	10.74

Clearly, in the case of stable import prices, by 2007 the introduction of CO_2 regulation will have led to no change in the domestic prices on the free market, if the CO_2 allowance price is €3 or €5/t. Even in the case of a €10 allowance price there would only be a 3% price increase on the free market. However, an import price growth caused by the introduction of CO_2 regulation would result in at least a 10% price increase on the free market.

Figure 3. Trend of the free-market price of power along with unchanged gas prices and import prices, as a result of different CO_2 allowance prices

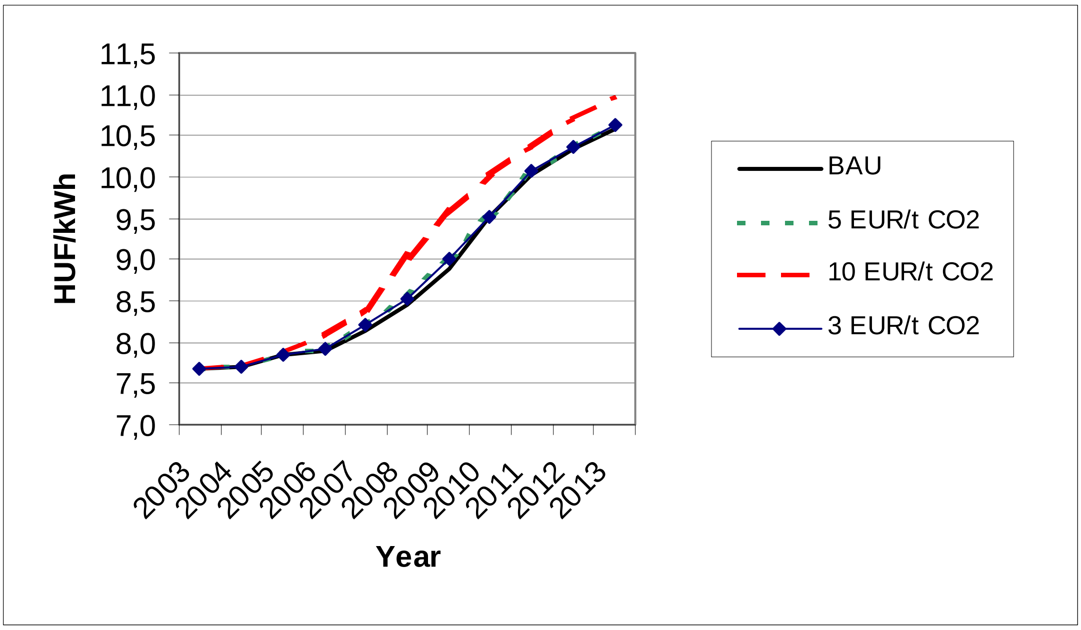
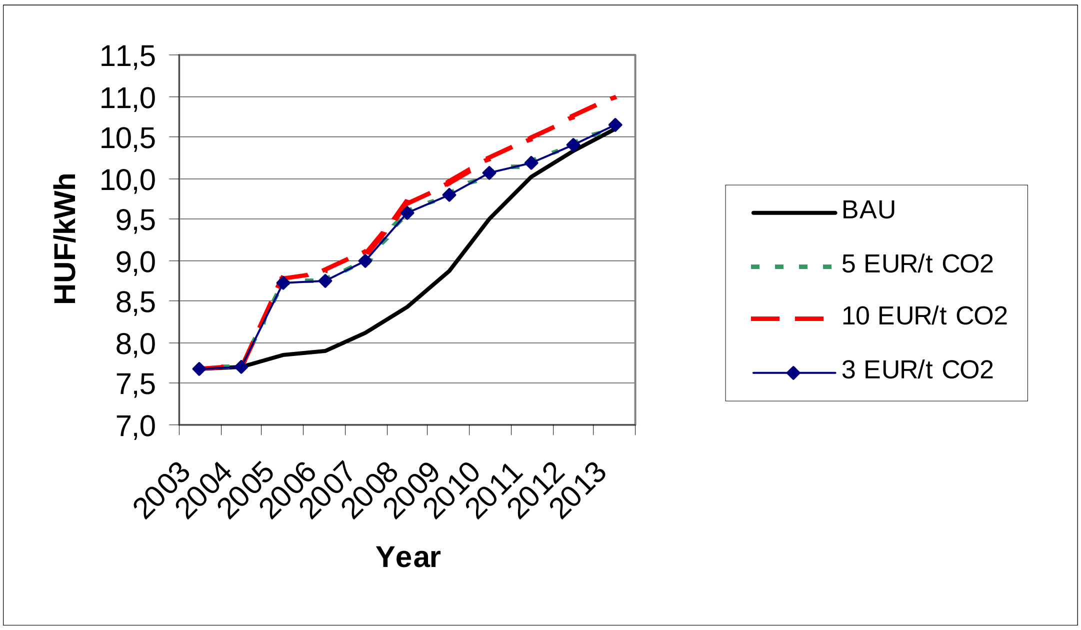


Figure 4. Trend of the free-market price of power along with unchanged gas prices and increasing import prices, as a result of different CO_2 allowance prices



Consumption will develop accordingly. The share of price-sensitive consumption will increase as a consequence of the growth of the free-market segment. This leads to a gradual divergence of the scenarios.

Table 6. Development of annual net consumption in the case of unchanged gas prices, unchanged or increasing import power prices and different CO_2 allowance prices, in GWh

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
BAU	33710	34687	35672	36744	37805	38773	39674	40274	40646	40857
of which free market	6571	8598	10255	12652	15052	17387	21463	25341	31052	31090
In the case of unchanged import power price										
€3/t CO_2	33710	34687	35672	36737	37767	38699	39538	40171	40531	40746
of which free market	*6571*	*8598*	*10255*	*12646*	*15014*	*17314*	*21326*	*25238*	*30936*	*30979*
€5/t CO_2	33710	34687	35672	36737	37764	38682	39498	40132	40520	40737
of which free market	*6571*	*8598*	*10255*	*12646*	*15012*	*17297*	*21286*	*25199*	*30925*	*30970*
€10/t CO_2	33710	34687	35664	36673	37629	38328	38898	39337	39684	39867
of which free market	*6571*	*8598*	*10247*	*12582*	*14876*	*16943*	*20686*	*24404*	*30089*	*30100*
In the case of growing import power price										
€3/t CO_2	33710	34687	35362	36150	36936	37522	38167	38760	39417	39922
of which free market	*6571*	*8598*	*10255*	*12646*	*15014*	*17314*	*21326*	*25238*	*30936*	*30979*
€5/t CO_2	33710	34687	35362	36150	36936	37522	38167	38760	39417	39922
of which free market	*6571*	*8598*	*10255*	*12646*	*15012*	*17297*	*21286*	*25199*	*30925*	*30970*
€10/t CO_2	33710	34687	35354	36110	36862	37423	38006	38528	39009	39347
of which free market	*6571*	*8598*	*10247*	*12582*	*14876*	*16943*	*20686*	*24404*	*30089*	*30100*

Note:

Self-consumption of power plants and network losses are not included in the net consumption figure.

The following figures show that, as a consequence of the increase in prices and the growth of price-flexible consumption, the rate of consumption growth declines in each scenario, just as it does without CO_2 regulation. Not surprisingly, the fastest decline in the rate of growth is expected in the case of an allowance price of €10/t, but this scenario also reveals an interesting finding that the introduction of CO_2 regulation has no effect on power consumption if import prices are stable and the secondary market price of CO_2 allowances does not exceed €5/t. In the case of higher import prices, consumption is reduced even if the allowance prices are lower.

Figure 5. Trend of annual consumption in the case of unchanged gas prices, unchanged import power prices and different CO_2 allowance prices

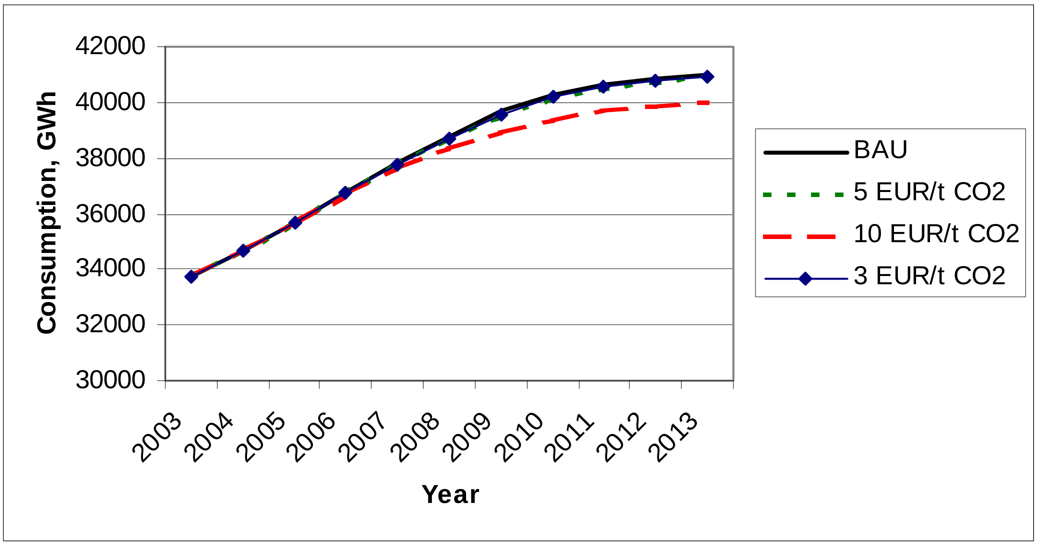
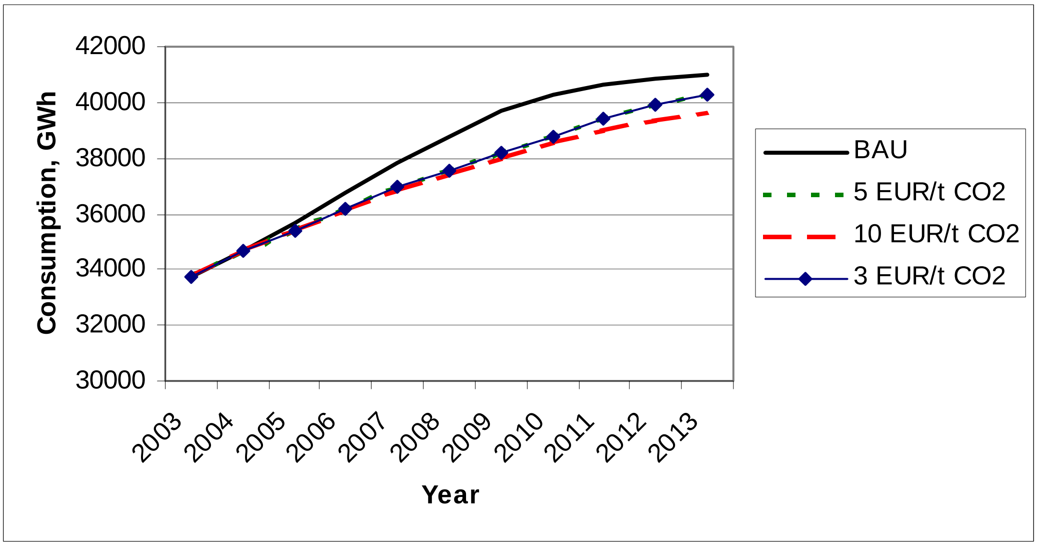


Figure 6. Trend of annual consumption in the case of unchanged gas prices, increasing import power prices and different CO_2 allowance prices



2.2 Models involving increasing gas prices

In another set of model versions the price of imported power is presented in two versions, just as above: in one alternative it is stabilised at the current price level, while in the other it grows gradually (as described above). The price of natural gas, however, is 15% higher throughout the period under review.

Table 7. Trend of free-market power price in the case of different CO_2 allowance prices, increasing gas price and standard or increasing import power prices, HUF/kWh

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
BAU	7.68	7.92	8.12	8.79	9.10	9.44	9.86	9.96	10.16	10.38
Unchanged import power price										
€3/t CO2	7.68	7.92	8.12	8.87	9.18	9.53	9.87	10.02	10.23	10.48
€5/t CO2	7.68	7.92	8.12	8.92	9.23	9.54	9.88	10.03	10.22	10.48
€10/t CO2	7.68	7.92	8.14	9.35	9.59	9.79	10.06	10.26	10.54	10.82
Growing import power price										
€3/t CO2	7.68	7.92	8.76	9.01	9.28	9.79	10.01	10.13	10.27	10.51
€5/t CO2	7.68	7.92	8.76	9.06	9.31	9.78	10.01	10.13	10.27	10.51
€10/t CO2	7.68	7.92	8.77	9.41	9.64	9.97	10.14	10.30	10.56	10.84

Following the introduction of CO_2 regulation, and given stable import prices, by 2007 the domestic price on the free market will be about 1% higher than if there were no regulation, provided the CO_2 allowance price does not exceed €3 or €5/t; if the allowance price equals €10/t the figure will be 5%. In the version with constant gas prices the figures will be 0% and 3%, respectively. An increase in import prices alongside the introduction of CO_2 regulation will mean that by 2007 prices on the free market will be about 2% higher than if there were no regulation, provided the allowance price does not exceed €5/t. The increase in the price of electricity will be 6% above the BAU level if the CO_2 allowance price is €10/t, which is less than the 10% price increase we saw irrespective of CO_2 allowance prices in model versions with stable gas prices and growing import electricity prices. The reason for this is that the basic model with an unchanged gas price, which assesses the development of the free-market price without CO_2 regulation, will result in a lower BAU price than the BAU prices of a basic model with increasing gas prices and without CO_2 regulation. It should be noted that, although the BAU scenario with an increasing gas price will result in a steadily higher free-market marginal cost than the BAU scenario without a gas price increase, the difference gradually diminishes because, by the end of the period under review, the basic model with an unchanged gas price has a similar price level – only reached with a slower growth rate – to the model with an increasing gas price.

Figure 7. The trend of the free-market price of power in the case of increasing gas prices and unchanged import prices, as a consequence of different CO_2 allowance prices

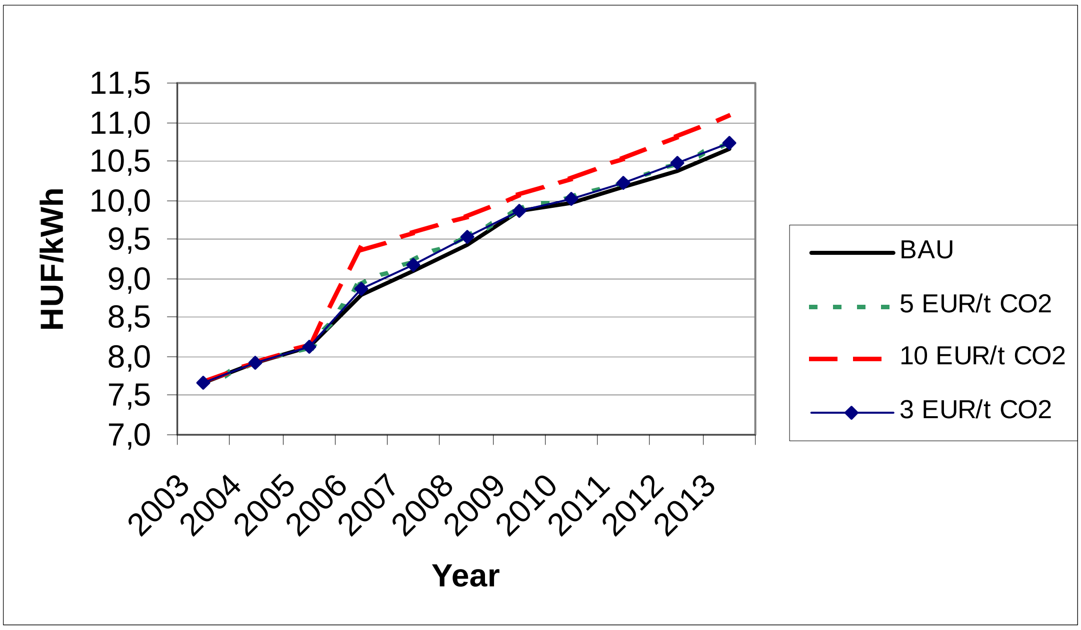
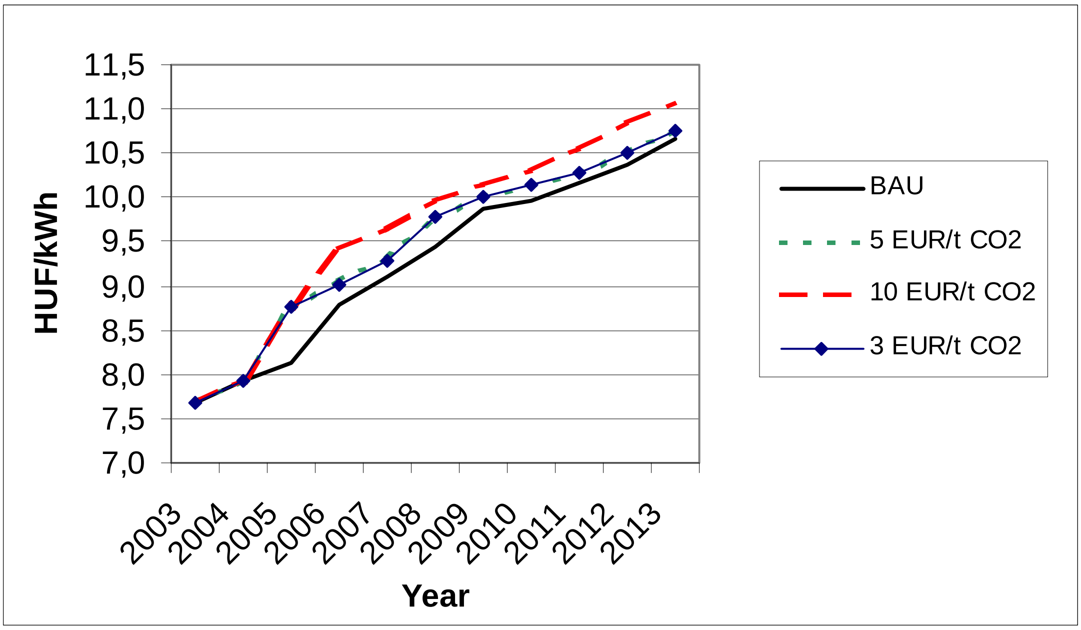


Figure 8. The trend of the free-market price of power in the case of increasing gas prices and import prices, as a consequence of different CO_2 allowance prices



It is clear that up to a €5/t CO_2 allowance price the price of imported power is dominant in our model, and only if the price of imported power grows does the free-market price depart as a consequence of the introduction of CO_2 regulation from the development of prices without regulation. In the case of an allowance price of €10/t the 'carbon effect' will be stronger and the free-market price will depart from the price in effect without regulation even if import prices remain unchanged. Below a given CO_2 cost level, then, the introduction of CO_2 regulation itself will have a smaller impact on domestic power prices if imported power prices are stable – even if the gas prices are higher – than if the imported power prices start to rise following the introduction of CO_2 regulation. This assumes not only that there will be a relatively substantial volume of imports, but also that, in the case of a CO_2 allowance price of €3 or €5/t, the majority of domestic power plants can continue generating at unchanged cost levels.

The following table presents the trend of annual consumption in the case of the model versions that assumed increasing gas prices.

Table 8. Trend of annual net consumption in the case of increasing gas prices, at unchanged or growing import power prices and different CO_2 allowance prices, GWh

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
BAU	33710	34620	35525	36264	36977	37627	38199	38863	39510	40001
of which free market	6571	8531	10108	12172	14224	16242	19988	23930	29915	30234
In the case of unchanged import power price										
€3/t CO_2	33710	34620	35525	36232	36921	37542	38132	38773	39392	39837
of which free market	*6571*	*8531*	*10108*	*12141*	*14168*	*16157*	*19920*	*23840*	*29798*	*30070*
€5/t CO_2	33710	34620	35525	36213	36883	37509	38101	38743	39373	39822
of which free market	*6571*	*8531*	*10108*	*12121*	*14130*	*16123*	*19890*	*23810*	*29779*	*30055*
€10/t CO_2	33710	34620	35521	36054	36614	37191	37764	38341	38828	39158
of which free market	*6571*	*8531*	*10104*	*11962*	*13861*	*15805*	*19553*	*23408*	*29233*	*29391*
In the case of growing import power price										
€3/t CO_2	33710	34620	35307	36014	36714	37256	37841	38484	39145	39633
of which free market	*6571*	*8531*	*9890*	*11923*	*13962*	*15870*	*19630*	*23551*	*29551*	*29866*
€5/t CO_2	33710	34620	35307	35997	36686	37241	37831	38478	39143	39632
of which free market	*6571*	*8531*	*9890*	*11906*	*13933*	*15856*	*19620*	*23545*	*29548*	*29865*
€10/t CO_2	33710	34620	35303	35870	36456	36984	37570	38172	38689	39042
of which free market	*6571*	*8531*	*9886*	*11778*	*13703*	*15598*	*19359*	*23239*	*29095*	*29275*

The growing importance of price elasticity is also evident here, as is the impact of price on consumption, where changes to the parameters of the model variables have smaller impacts than we saw in the case of the stable gas price models.

Figure 9. Trend in annual consumption in the case of increasing gas prices, unchanged import power prices and different CO_2 allowance prices

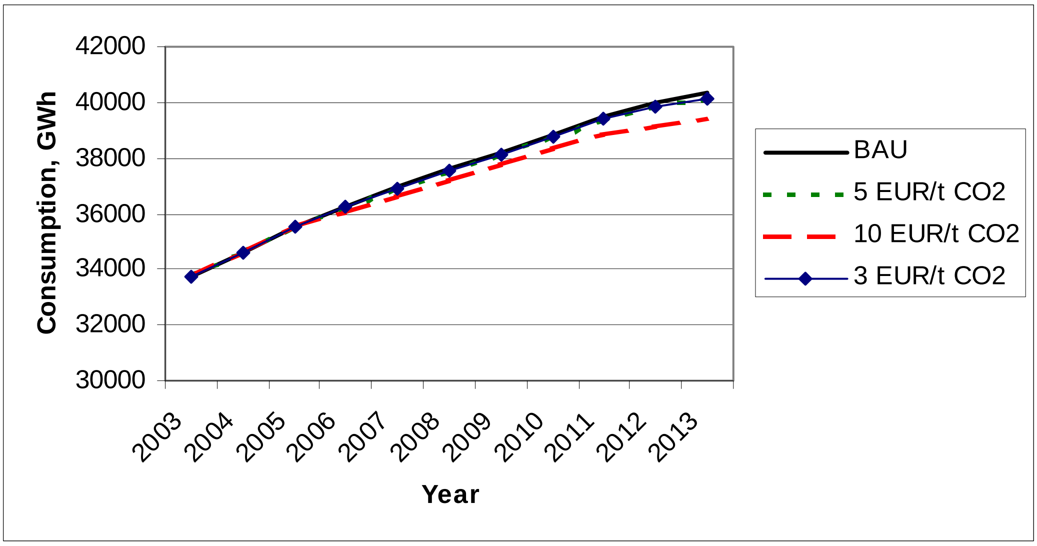
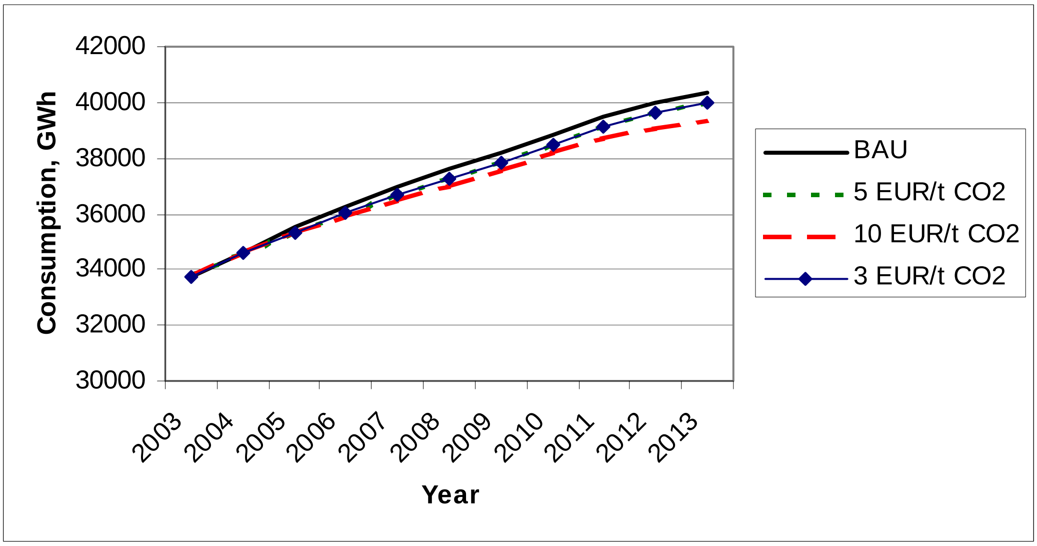


Figure 10. Trend in annual consumption in the case of increasing gas prices,increasing import power prices and different CO_2 allowance prices



Analysis of the above model versions shows that, for the power plants covered by the review, market share – market price and total CO_2 emissions – is influenced primarily by the development of import power prices, rather than by the domestic price level of natural gas (at least if gas prices are assumed to be at the current level or at a level 15% higher). However, the effects of the price of gas should not be ignored. For a change in the gas price modifies the basic version without regulation (BAU) to such an extent that the introduction of CO_2 regulation causes a smaller change in the price and in consumption in this case than the price change we see in the BAU versions when the 15% gas price increase is switched on and off. The models with unchanged gas prices will thus result in lower prices growing at a slower rate, and consequently in a more rapid growth in consumption, but the differences will diminish towards the end of the period under review.

The impact of the trend in the price of CO_2 emission allowances on the secondary market will operate in a complex way, for the various versions of the model respond in different ways to the allowance prices. The following is a description of the perceptible relationships between our results and CO_2 allowance prices.

2.3 CO_2 price sensitivity

The following two figures show the trend in the free-market price, along with a €3/t and a €5/t CO_2 allowance price. Some interesting factors are worth noting. The most important is that in the allowance price range between €3 and €5/t the results are not sensitive to change in the allowance price – the two figures are almost identical (the precise figures are listed in the previous section).

Figure 11. Development of the free-market price of power in the two basic models, and in the versions modelling CO_2 regulation involving a €3/t allowance price

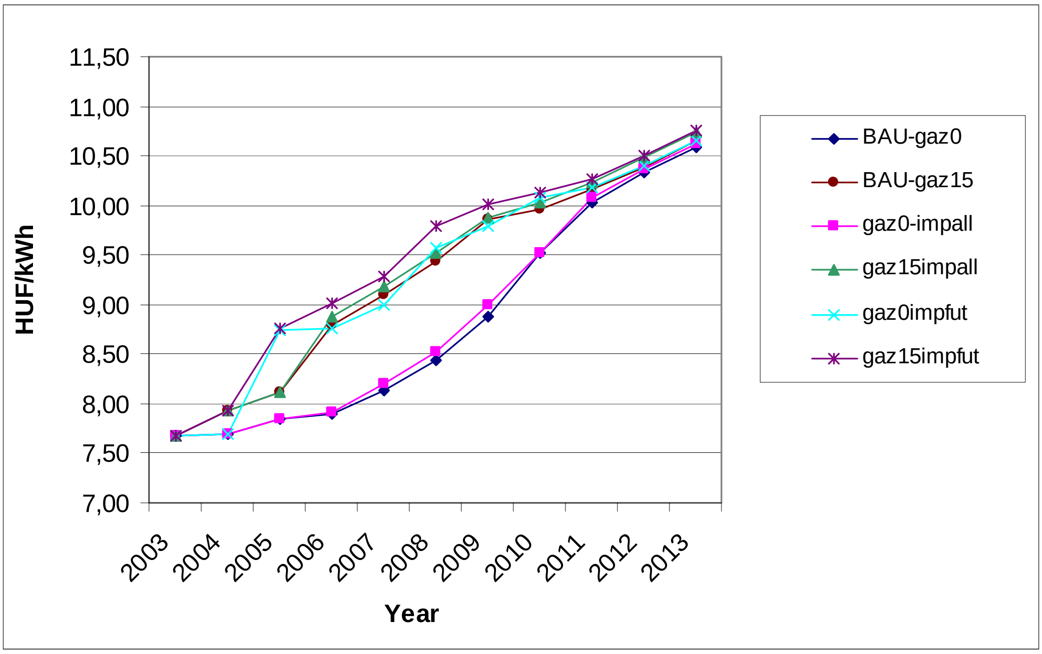
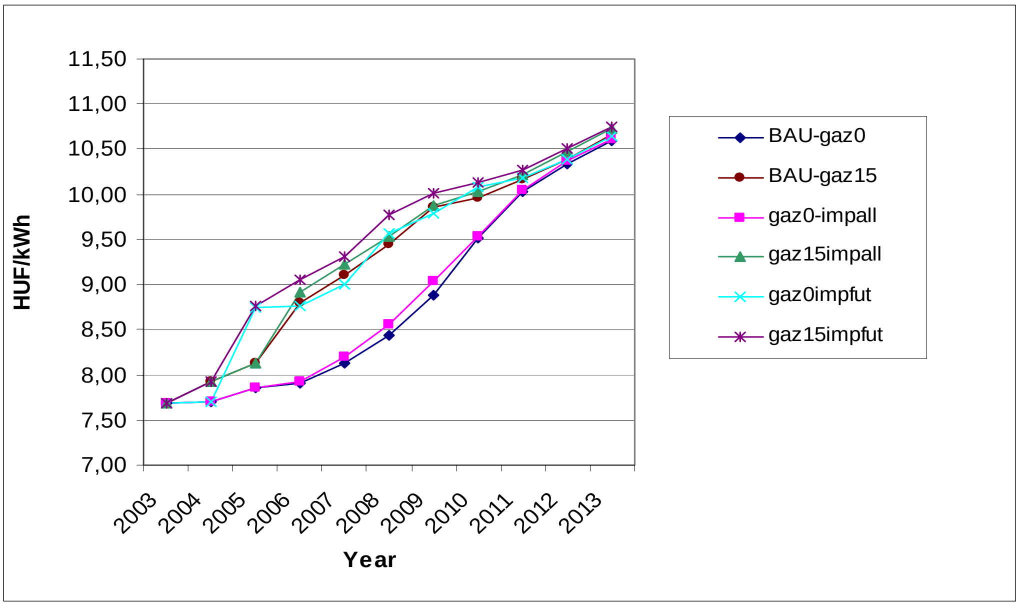


Figure 12: Development of the free-market price of power in the two basic models, and in the versions modelling CO_2 regulation involving a €5/t allowance price

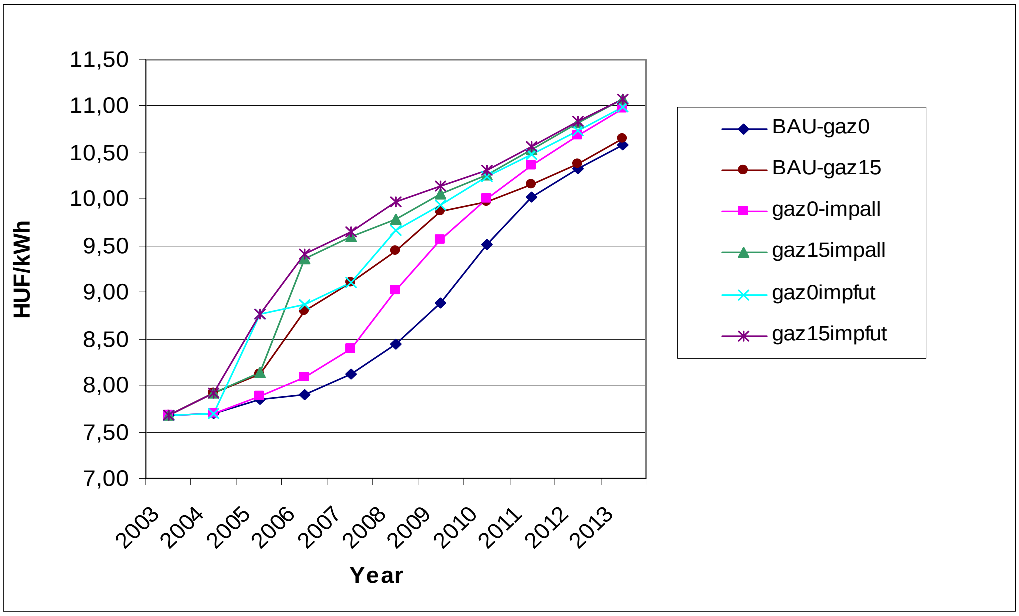


This is related to the fact that, in the case of allowance prices falling between €3 and €5/t, the development of the price of power is determined by the price level of imported power and the gas price level rather than by the introduction of CO_2 regulation. This is indicated by the fact that the basic model involving an increasing gas price (BAU-gaz15) departs from the basic model with unchanged gas price (BAU-gaz0) and it follows the CO_2 models involving increasing gas prices. By contrast, the model version with unchanged gas price and constant import price combined with CO_2 regulation (gaz0-impall) provides results that are very similar to the basic model with unchanged gas prices (BAU-gaz0) both in the case of a €3/t and a €5/t allowance price.

The third important comment is that, from 2011 on, the free-market prices will be identical, or at least very similar, in practically every model version. The reason for this is probably the scarcity of capacity, which will result in a similar price increase in the case of the €3 and the €5/t versions, and will slow the different rates of consumption growth in each version, leading to similar consumption levels by 2011–2012.

A €10/t allowance price will lead to results quite different from €3 or €5/t CO_2 allowance prices. The difference will be clear from a comparison of the following figure to the above two figures.

Figure 13. Development of the free-market price of power in the two basic models, and in the versions modelling CO_2 regulation applying a €10/t allowance price



The first thing to notice is the marked divergence between the various model versions, quite unlike the situation in the case of lower allowance prices. The most interesting behaviour is displayed by the model that assumes a stable import power price and an unchanged gas price (gaz0-impall). In the case of a €3 or €5/t allowance price this does not depart substantially from the basic model with unchanged price, but here it results in slowly but steadily higher market prices, and by 2012 it practically converges with the rest of the models with CO_2 regulation.

Different behaviour is exhibited in the case of a €10/t allowance price by the model with growing gas price (BAU-gaz15); in the case of a €3 or €5/t allowance price, its results cannot be separated from those of the models with CO_2 regulation. Accordingly, a €10/t allowance price seems to be a CO_2 cost, in the case of which even the basic model with growing gas price will depart from the versions modelling CO_2 regulation. Consequently, by the end of the period under review, the €10/t price does make a difference: the results based on CO_2 regulation and those without CO_2 regulation will diverge from one another, and the later calculations all forecast higher power market prices than the earlier ones.

2.4 The trend in CO_2 emissions

It should be noted that the total CO_2 allowance allocated by the latest published version of the National Allocation Plan to the power plants covered by our review is substantially higher in each of the scenarios than the total CO_2 emissions of the same power plants. The reason for this is complex and has come in for detailed analysis.

The CO_2 allowances contained in the NAP are based on a forecast,[12] the background studies and calculations for which come from the Ministry of Environmental Protection and Water Management.[13] A review of the calculations pertaining to power generators showed that the difference is explained by the following factors.

The sectoral projection for 2005 referred to in the NAP corresponds, more or less, to the medium- and long-term capacity plan to be found on the home page of MAVIR.[14] Our model contains the same capacity, utilisation and efficiency ratios as those published by MAVIR.[15] However, using the data contained there, and given a similar trend in consumption, the estimated supply-side structure will differ to a greater or lesser extent from MAVIR's supply structure for 2005.

According to the results of our calculations the largest difference is to be found in the import of power, which is always much higher in our models than in the sectoral projection referred to in the NAP. Consequently, according to the results of our models, domestic generation will be lower in the case of the same gross consumption, i.e. the total CO_2 emission will also be smaller.

The other main difference is the quantity of power bought up on a mandatory basis, of which our model also assumes large quantities. The compulsory power purchase applies to power generators or generation technologies to which preference is given under the relevant legal regulations (Power Act No. 2001/CX, Decree 56/2002 GKM). Most of the facilities concerned are power plants that generate power using renewable energy sources or are cogeneration plants. In our model the power generated by these is the quantity estimated by the current version of the relevant ministerial decree[16] and is substantially higher than the estimate contained in the NAP projection. This will also result in lower output among the large power plants covered by our review in the case of the same gross consumption level, for the larger quantity of power purchased on a mandatory basis will reduce the output of the other plants. At the same time, this could mean some tension between sectors I/a and I/b of the NAP (and to a lesser extent also between sectors I/a and I/c) if the results of our modelling hold, for large power plants may generate less and small power plants may generate more power than would be indicated by the distribution of the allowances.

Based on the above factors in the model versions where the introduction of CO_2 regulation increases the price of imported electricity, the difference between the

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[12] NAP section 8: Sectoral establishment of emission units.

[13] www.kvvm.hu/szakmai/klima

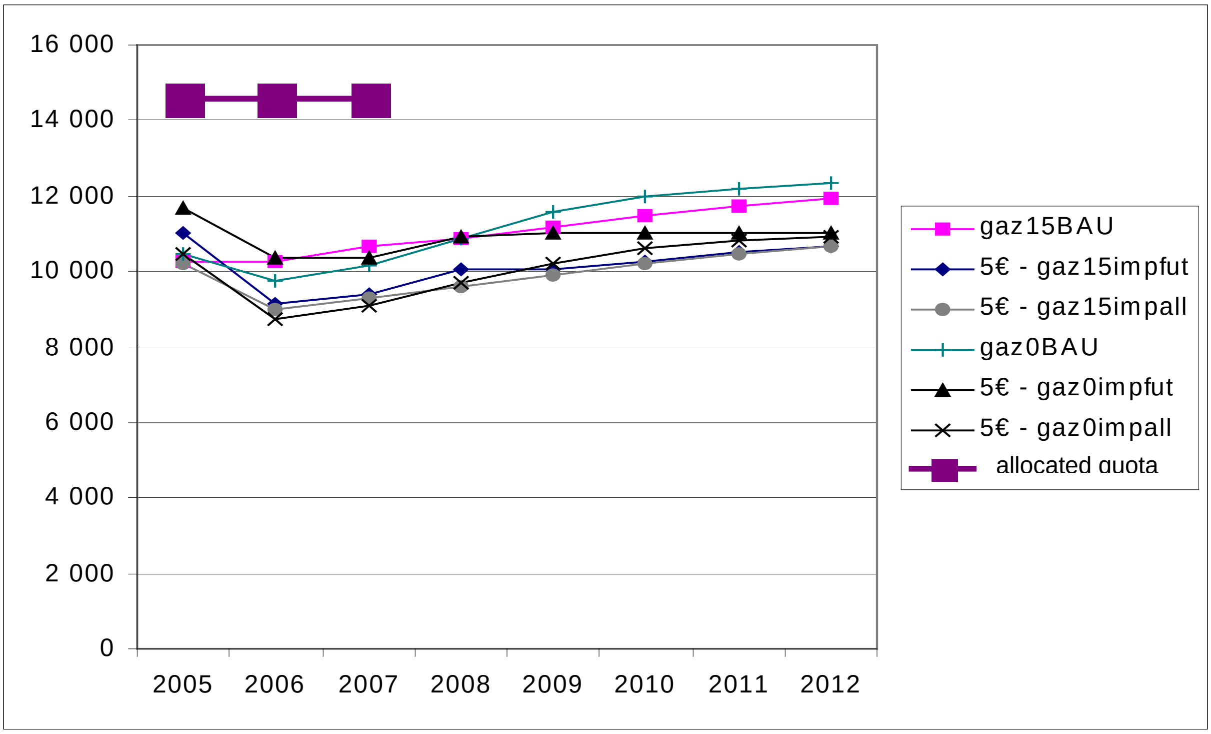
[14] Medium- and long-term supply-side capacity plan of the power system – Download, Annexes. www.mavir.hu

[15] Another source of data in addition to the MAVIR Mellékletek [annexes] file: *Villamos energia statisztikai évkönyv [Power industry statistics year book]*, 2001, 2002.

[16] Decree 56/2002 GKM on the rules of the purchase of power under compulsory power purchase and on the establishment of the prices applied; 17 July 2004; 30 December 2004.

CO_2 allowance quantities allocated free of charge in the NAP and the total quantity resulting from our calculations is smaller than in the versions with unchanged import prices. According to our own results, in the versions involving constant import prices a larger scale of power import may be expected, which will increase the difference between the actual CO_2 emissions of Hungarian power plants covered by our review and the quantity of CO_2 allowances allocated to them free of charge.

Figure 14. CO_2 emissions in the model versions with €5/t and the total quota quantity allocated in the NAP, kt

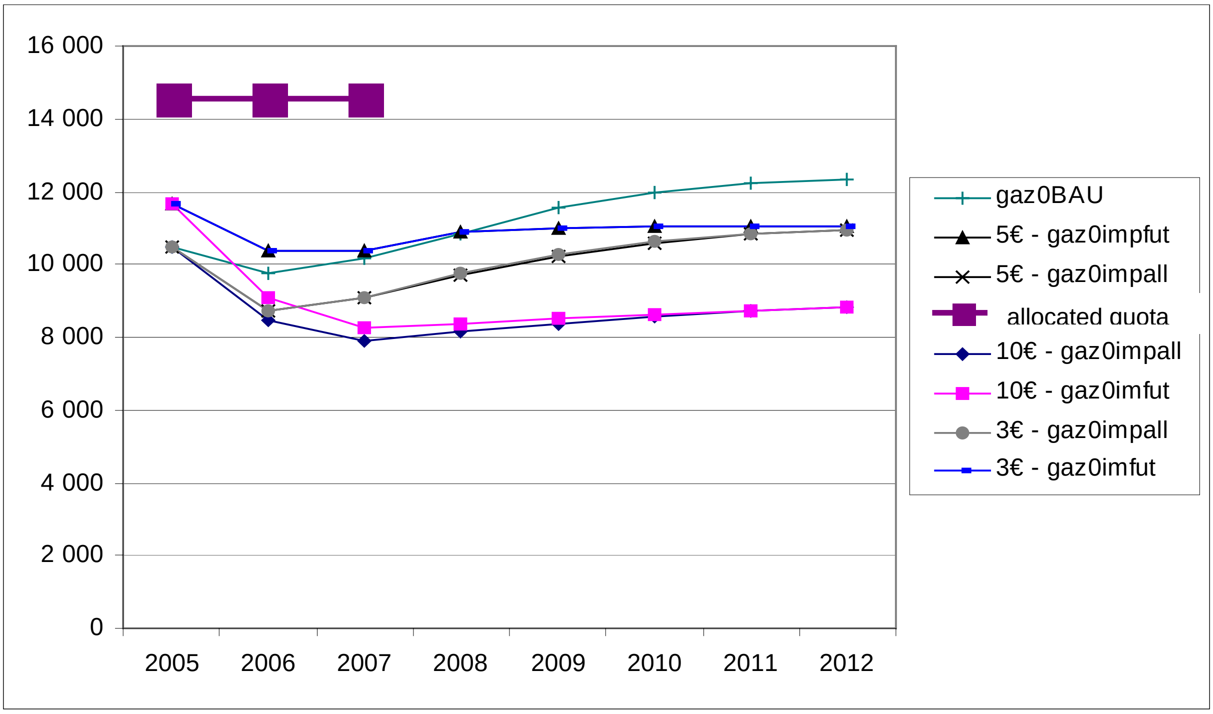


Three components of this over-allocation have been identified. The import, which we estimated at a substantially higher level, and the 'other' output – not falling in sector I/a – which is also estimated higher, do not fully explain the whole of the difference between the allocated quotas and the total CO_2 emission. In the various versions there is no explanation for at least 1–1.5 million tonnes of allowance surplus.

It should be noted that emissions in the BAU model with unchanged gas price approximate and then exceed emissions under the BAU model with a changing gas price by the end of the period under review. The reason for this is that in the scenario with an unchanged gas price there are fewer imports than in the case of the higher gas price, where the more expensive natural gas makes Hungarian generators less competitive than imported power; this will appear in increased imports as a result of the opening-up of the market.

The degree of over-allocation is presented in the case of the €3/t and the €10/t allowance prices as well. The following two figures show the impacts of the different CO_2 allowance prices on the development of emission levels.

Figure 15. The trend in total CO_2 emissions of the power plants under review in the case of unchanged gas prices and different CO_2 allowance prices, kt

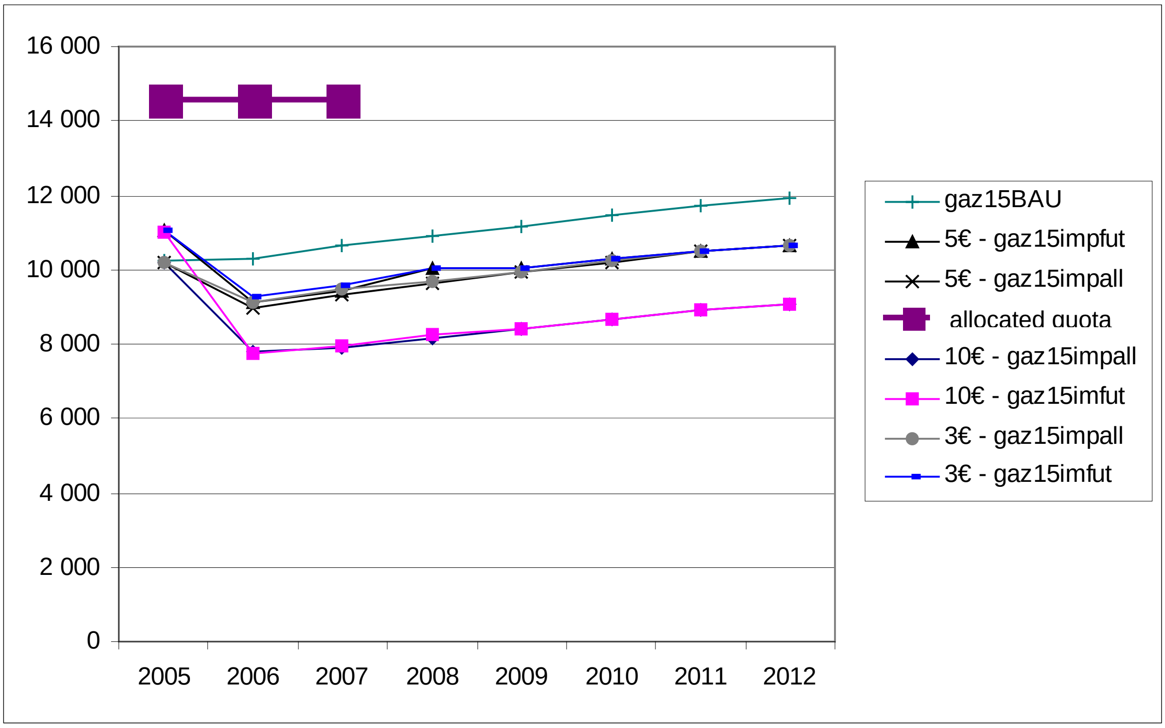


The over-allocation identified in the case of the €5/t allowance price is also observed in the case of the €3 and the €10/t CO_2 allowance price and in the case of unchanged gas price. Not just in the initial year, but throughout the period under review the total quantity of free allowances to be allocated under the NAP to the power plants covered by our study will substantially exceed the total emissions of the same group of power plants. The reason in each case is the development of imports and the output of the 'other' power plants, but some 1 million tonnes of allowances cannot be explained even by these two factors.

Given the market effects described earlier, regulation seems to have little impact on the free-market prices in the case of a €3 or €5/t allowance price and the quantities do not differ from one another in several model versions vis-à-vis the basic case without regulation. The above figure clearly shows that this applies only to the market effects, for total CO_2 emissions in the basic case without regulation significantly exceed the total CO_2 emission in the versions modelled with the €3 and the €5/t allowance price. In the case of the versions with the €3 and the €5/t prices, the emission path will not differ materially and by the end of the term the same total emissions will be reached.

The two versions with a €10/t price clearly differ from the above, since both the emission path and the stabilising total emissions level will be much lower than in the other versions. It is, therefore, an interesting lesson that, in the case of the €3 or the €5/t allowance price, the total supply-side CO_2 emissions of the power supply system will decline in such a way as will cause no material price increase or consumption decrease in the free-market segment in the majority of the model versions.

Figure 16. The trend in total CO_2 emissions of the power plants under review along with increasing gas prices and different CO_2 allowance prices, 1kt



Over-allocation is also observed in the case of the models that involve growing gas prices. The excessive quantity of allowances is explained, according to our calculations, by three components again, two of which are evident – the underestimation of the share of imports and the output of 'other' power plants on the supply side – while the third component is not explicable by the authors' model assumptions. Our emission results seem to be robust, since the three different emission paths and equilibrium emission levels appear equally clearly in the case of growing gas prices as well, and the results based on €3/t and €5/t are also quite closely aligned – unlike the models with unchanged gas prices – and this cluster is definitely lower than for emissions without regulation and higher than for emissions resulting from the application of a €10/t allowance price.

2.5 The possible revenue to the state

Finally, it should be noted that the 'allocated quantity of allowances' in the above figures shows the allowances allocated free of charge, i.e. the total quantity of allowances established for the power plants under review, net of a 2.5% share to be auctioned. This means that, in addition to the quantity to be allocated by the state free of charge, a total of 373 kt of CO_2 allowances may be sold on the European allowances market,[17] from which an **annual** revenue of HUF 280, 467 or 934 million may be earned in the case of an allowance price of €3, €5 or €10/t respectively, over a three year period (in 2005, 2006 and 2007).

Another source of state revenue could be the auctioning of the excess allowance that makes up the 'over-allocation'. This would involve different quantities under the different scenarios. The following table shows the state revenues that could be earned each year by selling the over-allocation surplus in the case of one of the most likely model versions (5€-gaz15impall) and the over-allocation surplus in the case of the highest initial emissions (with the smallest over-allocation) (5€-gaz0imfut).

Table 9. Possible state revenues from the sale of the surplus CO_2 emission allowances, HUF million/year

	CO_2 allowance	State revenue that may be achieved in the case of different allowance prices, HUF million/year		
	tonnes	€3	€5	€10
2.5% auction	373474	280	467	934
5€-gaz15impall	4365695	3274	5457	10914
5€-gaz0imfut	2898770	2174	3623	7247

If surplus allowances are sold, the buyers will probably come – rather than from the domestic power plants under review – from among those enterprises in the EU member states (through intermediaries) whose total allowance quantities are smaller than their CO_2 emissions and whose marginal CO_2 emission abatement costs exceed the equilibrium price that will prevail in the market of CO_2 emission allowances.

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[17] 'Pursuant to Article 10 of the Directive, 2.5% of the total emission units that may be allocated will be auctioned. The resulting revenue will be used by the budget for activities relating to emission abatement and for the supporting of renewable energy sources' (NAP, section 7).

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