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Impacts of carbon pricing, brown coal availability and gas cost on Czech energy system up to 2050

L. Rečka [a, b, *], M. Ščasný [a]

[a] Environment Center, Charles University in Prague, José Martího 407/2, 162 00 Prague, Czech Republic
[b] Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Opletalova 26, 110 00 Prague, Czech Republic

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ABSTRACT

A dynamic partial equilibrium model, TIMES (The Integrated MARKAL-EFOM System), is built to optimize the energy system in a post-transition European country, the Czech Republic. The impacts of overall nine scenarios on installed capacity, capital and fuel costs, air quality pollutant emission, emission of CO_2 and environmental and health damage are quantified for a period up to 2050. These scenarios are built around three different price sets of the EUA (EU allowance) to emit greenhouse gasses alongside a policy that retains the ban on brown coal mining in two Czech mines, a policy that will allow the re-opening of mining areas under this ban (i.e. within the territorial ecological limits), and a low natural gas price assumption. We found that the use of up until now dominant brown coal will be significantly reduced in each scenario, although reopening the coal mines will result in its smaller decline. With low EUA price, hard coal will become the dominant fuel in electricity generation, while nuclear will overtake this position with a 51% or even 65% share assuming the central price of EUA, or high EUA price, respectively. The low price of natural gas will result in an increasing gas share from an almost zero share recently up to about 42%. This stimulus does not however appear at all with low EUA price. Neither of these scenarios will achieve the renewable energy sources 2030 targets and only a high EUA price will lead to almost full de-carbonization of the Czech power system, with fossil fuels representing only 16% of the energy mix. The low EUA price will result in an increase in CO_2 emissions, whereas the high EUA price will reduce CO_2 emission by at least 81% compared to the 2015 reference level. Those scenarios that will result in CO_2 emission reduction will also generate ancillary benefits due to reduction in air quality emissions, on average over the entire period, at least at 38€ per t of avoided CO_2, whereas scenarios that will lead to CO_2 increase will generate ancillary costs at least of 31€ per t CO_2.

1. Introduction

Which fuel mix will be used to generate energy in the future? This is the dilemma recently widely discussed in order to minimise the environmental burden attributable to energy generation and mitigate climate change. But not only that; the fuel mix will also affect energy security and dependency on fuel imports of a given country. Undesirable energy prices increases may then jeopardise vulnerable households, increase fuel poverty and induce social problems. All of these problems may arise more pressingly particularly in the post-transforming countries, such as countries from Central and Eastern Europe, in which the energy systems exhibit similar features. First of all, at the beginning of the 1990s, the energy intensity of economic production in all of these countries was several times larger than in Western Europe [1] and no comprehensive policy and regulatory framework for energy efficiency and renewable energy were established in the Czech Republic before the accession to the EU (European Union) in May 2004 [2]. Since the energy efficiency alongside with GDP is expected to significantly converge with the EU average level in the most of CEE (Central and Eastern Europe) countries during the period to 2020 [3], new energy sources will have to satisfy strict requirements on efficiency without increasing energy consumption further. Second, in terms of the fuel mix, primarily energy production in the power sectors has been dominated by domestic coal (Czech Republic, Slovakia, and Poland) and nuclear power (Czech, Slovakia, and Hungary), with a high share of combined generation of electricity and heat, and a very small contribution of renewable energy. Public research and

* Corresponding author.
E-mail address: lukas.recka@czp.cuni.cz (L. Rečka).

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development expenditures on energy technologies, including renewables, remained low in the CEE region even at the end of the 2000s [4]. Third, energy generation was generally heavily subsidised not only before these countries transformed their economies into market systems, but even after this period during the 1990s. Heavily subsidised district heating prevailed for a long time, making the residential heating supply a politically hot issue. Fourth, the pollution intensity of the power sector dramatically declined during the 1990s and beyond as an effect of the implementation of EU environmental regulations (see, for instance, Ščasný & Menkyna [5]). However, the airborne emissions stemming from power sector was reduced mostly by command-and-control measures, while economic instruments have so far remained ineffective in most CEE countries, as found by Máca et al. [6]. However, new impetus has come recently from the European Union; each CEE country, as a member of the European Union, has to comply with current EU climate and energy policy, which first set its 20-20-20 target to be achieved by 2020, updated in 2014 by setting the EU policy commitment 40-27-27 by 2030[1] [7] which was integrated into the EU Roadmap for moving to a competitive low-carbon economy [8] that requires reducing greenhouse gas emissions to reach 80% below the 1990 level by 2050.

The energy infrastructure inherited from the past, abatement adopted mostly through the end-of-pipe technologies and the EU climate-energy policy all determine the structure of national energy systems in all CEE countries, including their fuel mix and technology mix. On top of that, the national energy systems are and will continue to be significantly constrained by new a regulation that has been recently discussed at national level. In this paper, we explore how the energy system in one post-transforming country in the CEE region may develop. Specifically, we model the energy system for the Czech Republic over the period up to 2050 considering recently discussed regulations and changes in policy trends, which are also very relevant for other countries from this regional block.

The Czech Government is currently discussing the possibility of revoking its past binding decision and to 'break' the territorial ecological limits in order to ensure a supply of high quality domestic brown coal. Breaking the limits would result in re-opening two brown coal mines which have been under a ban since 1991,[2] with 123–270 kt of brown coal newly available over the period of 2016–2050 [9]. Hand-in-hand with the territorial ecological limits on brown coal mining, there has been another political debate on building additional nuclear reactors to combat climate change and increase energy safety, The use of renewable energy resources has increased significantly in the Czech energy mix since 2010 reaching 10.5% of electricity and 12.5% of heat

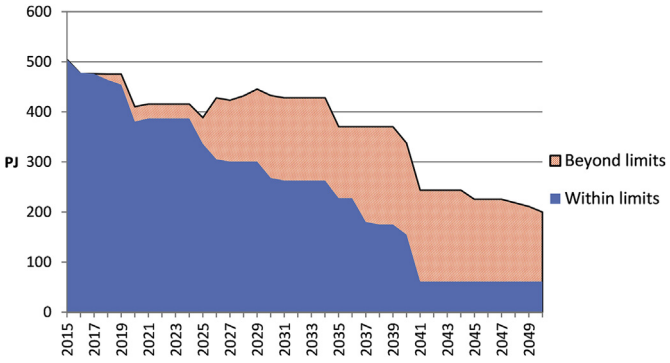

Fig. 1. Expected brown coal exploitation in the Czech Republic until 2050 - within and beyond territorial mining limits. Source: Author's illustration based on [16].

generated [4], especially thanks to high feed-in-tariffs provided particularly for wind power and photovoltaics. However, since 2014 the Czech government no longer subsidises new photovoltaic and biogas power plants and will stop subsidising all other renewable sources except small hydro from 2016 [10]. Still, the share of renewables will have to increase to meet the 20% by 2020 and the 27% by 2030 EU targets.

This paper enriches the energy modelling literature threefold. First, a dynamic partial equilibrium energy model of a Czech energy system in the TIMES (The Integrated MARKAL-EFOM System) model generator is developed that is enriched by very detailed facility-level technology, emission, and economic data.[3] Second, we use the TIMES model to predict the energy mix up to 2050 taking into account all the policy facts and prospected regulations as mentioned above. Specifically, we compare the effect of three scenarios assuming (i) a policy that retains the ban on extending the coal mines, (ii) a policy that is breaking the ecological territorial limits, and (iii) a scenario assuming the low price of natural gas. We then assume three sets of EUA (EU allowances) prices for each of the three scenarios, having in total nine scenarios, including the baseline (keeping the limits, central value of the EUA and gas price). Third, in addition to the impact on installed capacity, technology and fuel mix, and costs, we also quantify the external cost associated with airborne emissions related to each scenario using the ExternE methodology [11–13].

We found that the EUA price is the main driver of Czech energy system development and it determines the course of CO_2 emissions. Reopening the coal mines will result in a smaller decline of the brown coal share on electricity generation. With low EUA price, hard coal will become dominant in electricity generation, while nuclear will overtake this position with a 51% or even 65% share assuming the central price of EUA, or high EUA price, respectively. The lower price of natural gas will result in its increasing share from what has recently been an almost zero share

[1] The EU targets set to be achieved by 2030 include 1) to reduce EU's GHG emissions by at least 40% relative to the 1990 level; 2) to increase the share of renewables to at least 27% of the EU's final energy consumption; and 3) to increase energy efficiency by at least 27%. These new 2030 EU targets will be accompanied by the reform of the EU Emission Trading System and by a complex of measures to achieve a competitive, affordable, secure, and sustainable energy supply for the EU [50].

[2] Since 1991 the territorial ecological limits have been set on the brown coal reserves in the Northern Bohemia, and as a result, any expansion of the brown coal mining at *Bílina Mine* and coal mine opening in *ČSA Mine* have been banned. The limits define the areas where an open-pit mining is allowed and where it is not. Territorial limits to the mining of brown coal in North Bohemia are legally binding according to Decrees No. 331 and 444 on *Territorial Environmental Limits on Mining* passed in 1991, and further confirmed by Decree 1176/2008, by the Government of the Czech Republic. The re-opening of two brown coal mines has been motivated for long time by social concerns about cost of centrally supplied heat to households and due to energy dependency concern – the two sensitive political issues which have been persisting in a policy debate over past two decades in the most of CEE countries with formerly socially planned economies.

[3] The development of energy systems over a long time period has been modelled mainly at EU-level (e.g. Capros et al. [51], Blesl et al. [52], EC [53], Bussar et al. [54], Spiecker & Weber [55], Dowling [56]) or 'western' countries (e.g. Amorim et al. [57], Gerberová et al. [58] and Rosenberg et al. [59]), but there are only a few applications of energy modelling in the CEE region (e.g. Sáfián [60]), and in the Czech Republic in particular. To date, only a linear optimization model EFOM/ENV (Energy Flow Optimisation Model) has been used to evaluate some policy documents prepared by the Czech Ministry of Industry and Trade or Ministry of the Environment of (e.g. MPO [61]), however the EFOM/ENV model is less detailed and uses older data than the presented model. Rečka & Ščasný [45] apply a linear optimization model MESSAGE (Model for Energy Supply System Alternatives and their General Environmental Impacts), analysing the power sector only.