Review paper

Received: July 17, 2013
Accepted: October 25, 2013

Analysis of global projections for primary energy resources supply – importance and role of coal in world and in Slovenia

Analiza globalnih projekcij za oskrbo s primarnimi energijskimi viri – pomen in vloga premoga v svetu in v Sloveniji

Evgen Dervarič
University of Ljubljana, Faculty of Natural Sciences and Engineering, Aškerčeva 12, 1000 Ljubljana, Slovenia
Corresponding author. E-mail: evgen.dervaric@ntf.uni-lj.si

Abstract

According to BRG (German Federal Institute for Geosciences and Natural Resources) data from 2010 in the world structure of global energy reserves, there is still available 24.2 % of oil, 17.6 % of gas, 4.3 % of uranium and thorium and other 53.8 % of all categories of coal. Coal is the only resource among the fossil fuels, which will remain in the energy market the longest, due to the large volume of reserves around the world. World proven reserves at the end of 2010 reached 729 billion tons. The EU's dependence on fossil fuel imports will significantly increase from 2010 to 2030[1] namely, the amount of coal will reduce in 2030 for 63 % (2010 – 48 %), for oil 95 % (2010 – 86 %) and for gas 84 % (2010 – 64 %). Fossil fuels remain the dominant primary energy resource worldwide and represent the projection of more than three-quarters of all consumption in the period up to year 2035.

The scope and effectiveness of strategic measures for preventing climate changes remains a major factor that cannot be predicted for the future direction of development of the coal market, but in any case the world cannot waive the coal. According to current scenarios, it is expected that the growth rate of CO_2 emissions from coal will amount to 1.5 % between 2007 and 2030 (1990 – 20.9 Gt, 2007 – 28.8 Gt, 2020 – 34.5 Gt, 2030 – 40.2 Gt). The combined efforts in the fight against climate changes we are currently facing around the world and development of new energy technologies including the usage of CCS (Carbon Capture and Storage) technologies could lead to lower CO_2 emissions.

Key words: energy demand, energy supply, coal, CCS (Carbon Capture and Storage), UCG (Underground Coal Gasification)

Izvleček

V strukturi globalnih energijskih rezerv po podatkih BRG (German Federal Institute for Geosciences and Natural Resources) iz leta 2010 imamo na svetu na voljo še 24,2 % nafte, 17,6 % plina, 4,3 % urana in torija ter 53,8 % vseh vrst premoga. Premog je med fosilnimi gorivi edini vir, ki bo na energijskem trgu zaradi velikega obsega zalog po vsem svetu ostal najdlje. Dokazane rezerve so konec 2010 dosegale 729 milijard ton.

Odvisnost EU od uvoza fosilnih goriv se bo od leta 2010 do leta 2030 bistveno povečala[1], in sicer bo za premog v letu 2030 63 % (2010 – 48 %), za nafto 95 % (2010 – 86 %) in za plin 84 % (2010 – 64 %). Fosilna goriva ostajajo dominanten primarni svetovni energijski vir in pomenijo v projekcijah več kot tri četrtine povečanja vse porabe v obdobju do leta 2035.

Obseg in učinkovitost strateških ukrepov za preprečevanje klimatskih sprememb ostaja še naprej glavni dejavnik, ki ga ni mogoče napovedati za prihodnje smeri razvoja trga premoga, se pa premogu v svetu po nobenem scenariju ne bomo mogli odpovedati. Po sedanjih scenarijih se pričakuje, da bo stopnja rasti emisij CO_2 iz premoga 1,5 % med leti 2007 in 2030 (1990 – 20,9 Gt, 2007 – 28,8 Gt, 2020 – 34,5 Gt, 2030 – 40,2 Gt). Združena prizadevanja v boju proti klimatskim spremembam, kot smo jim sedaj priča po celem svetu, bi z razvojem novih tehnologij v energetiki vključno z uporabo CCS-tehnologij (zajem in skladiščenje ogljika) lahko vodila do nižjih emisij CO_2.

Ključne besede: energijske potrebe, oskrba z energijo, premog, CCS (zajemanje ogljika in skladiščenje), UCG (podzemno uplinjanje premoga)

Introduction

The projections for world energy supply with primary energy products are nowadays facing a relatively large uncertainty, which was caused by the global economic crisis in the years 2008 and 2009.

In Slovenia, we are confronted with the consequences of the crisis in 2013. All the world's governments are confronting with three long-term challenges related to the climate changes, as well as the reliability and security of the energy supply[2]. Additional considerations of energy supply in the world arose in the recent natural disaster in Japan. The first move by the German government's decision was to close all nuclear power plants by 2022, bringing about radical changes in Germany's energy strategy, which substantially desires to accelerate the deployment of renewable energy resources, and thus by 2022 replace the nuclear energy. Expert public is sceptical towards a realistic estimation of policy decisions.

Primary energy demand in the world

In[3], published by the International Energy Agency (IEA) based in Paris; the world's future energy scenarios are focused on three projections, namely current policies scenario, in the publication[4] so-called reference scenario, new policies scenario (this is associated with already reached agreement on reduction of greenhouse gas emissions and despite the reduction of emissions there is considerable uncertainty as Kyoto Protocol commitments expire by 2013 and there haven't been no new agreements yet in Copenhagen and Cancun) and the third 450 scenario (this scenario takes into account to limit CO_2 emissions to 450 ppm CO_2).

The scenario and the direction we will adjust in the future, largely depends on the countries around the world. China and India will play an important role in these arrangements, and with their large reserves of coal, economic growth certainly will not be able to denounce them in the future.

The volume of primary energy demand in the world with regards to fuel type is described in Table 1. Fossil fuels remain dominant primary energy resource and represent in the projections more than three-quarters of all fossil fuels spent by the year 2035. Coal is mainly devoted to the energy sector or electricity production, increased consumption by 2035 is planned at an annual rate of 2.2 %.

Coal demand in the world

Five world's largest consumers of coal, China, the USA, India, Japan and Russia together account for 72 % of world coal consumption. Under the current scenario, the IEA (current policies scenario) should reach an average growth of coal by 2015 at 3.1 % per year until 2015 and 1.3 % per year between 2015 and 2035. Demand for coal will largely depend on envi-

Table 1: *Primary energy demand (based on fuel) in the world depending on particular scenario (in Mtoe – 1 t of oil equivalent = 42 GJ)[3]*

			new policies scenario		current policies scenario		450-scenario	
	1980	**2008**	**2020**	**2035**	**2020**	**2035**	**2020**	**2035**
Coal	1 792	3 315	3 966	3 934	4 307	5 281	3 743	2 496
Oil	3 107	4 059	4 346	4 662	4 443	5 026	4 175	3 816
Gas	1 234	2 596	3 132	3 748	3 166	4 039	2 960	2 985
Nuclear	186	712	968	12 773	915	1 081	1 003	1 676
Hydro	148	276	376	476	364	439	383	519
Biomass and waste	749	1 225	1 501	1 957	1 451	1 715	1 539	2 316
Other renewable	12	89	286	699	239	468	325	1 112
Total	7 229	12 271	14 556	16 748	14 896	18 048	14 127	14 920

ronmental commitments of all countries in the world the possible scenarios are shown in the Figure 1.

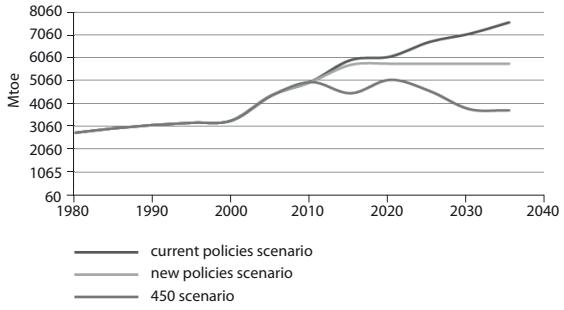

Figure 1: *Coal demand depending on scenario[3].*

The projections of coal demand in the world show a substantial reduction of its demand in OECD countries, whereas in other parts of the world as in Table 2 showing the increase of coal usage. Growth in the share of coal in total energy supply will increase from 26 % in 2006 to 29 % by 2025. By 2030, China will spend 50 % of world coal. In India, there has been the second largest growth in coal demand (in the year 2030 it would exceed the USA).

Reserves and production of coal in the world

Coal as a fossil fuel is among primary energy resources most widely available and the most geographically dispersed. The world proven reserves have reached 729 billion tons at the end of 2010 BRG (German Federal Institute for Geosciences and Natural Resources). Figure 2 shows the global energy reserves, whereas 53.8 % from all reserves present bituminous and sub-bituminous.

In the period between 2006 and 2030, it is expected that coal production will increase by 52 % (+ 2,397 Mtce)[2], at an average annual

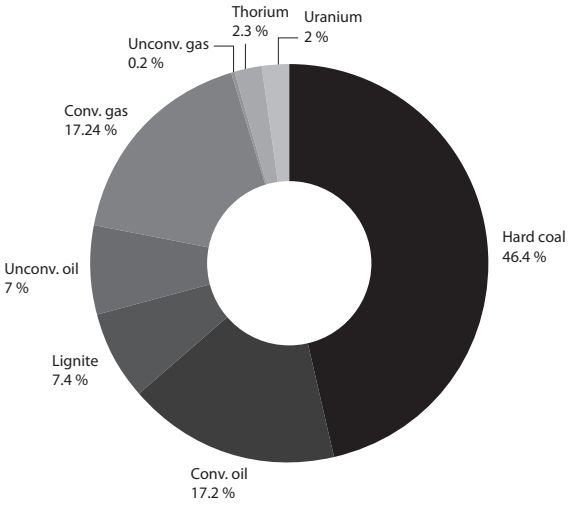

Figure 2: *Global energy reserves[5].*

rate of 1.8 % (OECD, in the same period registered a growth of only 0.3 % per year). The USA will remain the largest producer in the OECD with increase of 18 % between 2007 and 2030. In non-OECD countries, it is expected 2.4 % annual increase to meet domestic demand. Energy coal for electricity production is expected to grow by 2.2 % per year; its share in electricity production is expected to increase from 77 % in 2007 to 81 % in 2030.

Reserves and coal production in Slovenia

Of fossil fuel energy resources, Slovenia has only coal, which is the reason that Slovenia has to handle its reserves and exploitation in the most rational way. Since the EU does not control oil and gas markets, the risks in the supply are extremely high. Despite all the economic and environmental disadvantages of coal, EU will not significantly reduce its current consumption. Major coal beds in Slovenia are in Velenje, Zasavje and Prekmurje.

Table 2: *Coal demand in particular regions and scenarios (in Mtce – 1 t of coal equivalent = 29,3 GJ)[3]*

			new policies scenario		current policies scenario		450-scenario	
	1980	**2008**	**2020**	**2035**	**2020**	**2035**	**2020**	**2035**
OECD	1 379	1 612	1 452	1 021	1 596	1 507	1 348	709
Non-OECD	1 181	3 124	4 213	4 600	4 557	6 037	3 998	2 856
Total	2 560	4 736	5 665	5 621	6 153	7 544	5 347	3 566

Velenje

Balance reserves of lignite in a coal bed in Velenje coal mine (PV) in the Šalek valley are on the day 31. 12. 2008 estimated to 171 million tons[6] exploitation reserves are 131.67 million tons with an average calorific value 10.47 J/kg. The situation is summarized from the elaborate of the classification and categorization of the calculated reserves and resources of coal in the Velenje Coal Mine from December 2008[7]. Projections for future coal production are linked to long-term operation of Thermal Power Plant Šoštanj (TEŠ), which will with the investment in block 6 with a power of 600 MW replace the electricity generating compensation from blocks 1, 2, 3, 4 and 5. PV is the only supplier of coal for the TEŠ. In Šalek valley, in the so-called Šoštanj's part of deposit, there is approximately 90 million tons of coal balance reserves and based on estimation we could gain about 60 million tons of coal to the surface. The Velenje Coal Mine has temporarily waived to its exploitation. Using conventional methods of excavation and requirement of excavation without the surface subsidence in exploitation of this coal would not be economically justified[8].

Forecast level of coal production until 2015 is 4 million tons per year, by 2040 it will be gradually reduced to the amount of 2 million tons per year and will remain at that level until the end of exploitation of Velenje's excavation field, which is expected to be until 2054. Long-term preservation of lignite mining in the Velenje Coal Mine is important for diversification of energy resources, particularly for electricity production. As a domestic energy, resource lignite significantly reduces the risk of the energy supply in the exceptional economic and political circumstances. In accordance with the needs of the TEŠ, the level of annual coal production is consistent from the PV by the year 2054. After 2014, the starting price of coal from the PV will be 2.25 EUR /GJ.

Zasavje

The Republic of Slovenia has, with the law on the gradual closure of Trbovlje-Hrastnik mine (RTH) and development of restructuring of the region (Official Gazette RS, no. 61/2000)[9], decided to close the brown coal mines in Zasavje. The production price of coal by the end of the estimated production of coal shall not exceed more than 3.0 EUR/GJ. Thermal Power Plant of Trbovlje (TET) expires in 2017. TET is planning to produce electric energy with the existing facilities until this year, as more strict environmental protection requirements will be established for which the existing plant is not appropriate. Excavation of potential reserves, which in 2009 were still about 24 million tons of coal (detailed report on reserves with the situation on 31. 12. 2002), RTH has recorded 53 million tons[10] in the balance sheet reserves, of which 24 million tons were excavated at an average heating value 11 MJ/kg. TET is an important energy location for Slovenia, but there have not been any decisions taken regarding its modernization yet.

Prekmurje

In the western part of Goričko in Videm by Ščavnica, Presika and between Lendava and Petišovci, some potential sub-bituminous reserves 830 million tons[11] were discovered. The most important is the area in the western Goričko from Strukovci to Kuzma. The quality of coal is better than the quality of all brown coals in Slovenia. Calorific value is 17.5 MJ/kg and combustible sulphur content is 0.91 %. Coal is just below the surface. It is expected that on the area of 50 km^2 to a depth of 250 m there are around 450 million tons of potential coal reserves. Coal seam thickness is between 10 m and 12 m. Estimations of coal resources are based on Goričko research boreholes and well logging measurements from drilling for oil, and it would be necessary to confirm this coal reserves with appropriate geological research works (mapping, drilling and sampling) and pre-categorisation of reserves from existing category D in the category C2. Coal reserves, located in Prekmurje are needed to be explored in the future. Underground coal gasification technology (UGC) will in the future (because of the nuclear disaster in Japan) have experienced a significant development steps and the cost and environmental and will with cost and environmental high probability approximation approach to commercial applications. Coal reserves and their exploitation in Prekmurje is not appropriate to bind on the conventional mining, but on the mining of underground gasi-

fication technology, which is shortly described in chapter entitled: Alternative energy supply.

Coal and CO_2 emissions

The extent and effectiveness of strategic measures to prevent climate changes remains a major factor that can not be predicted for the outlook of development of the coal market in the future. Projections of the modernization of combustion plants and CO_2 reductions is shown in Figure 3 under the current scenario, it is expected that CO_2 emissions from coal reach an annual growth of 1.5 % between 2007 and 2030 (1990 – 20.9 Gt, 2007 – 28.8 Gt, 2020 –34.5 Gt, 2030 – 40. 2 Gt).

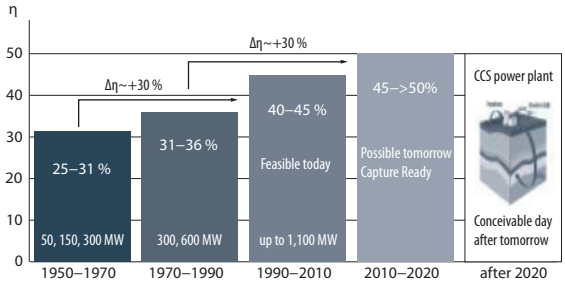

Figure 3: *Technology development and modernization of combustion plants and process of CO_2 reduction*[12].

The combined efforts in the fight against climate changes that we are currently witnessing around the world, including the use of CCS (Carbon Capture and Storage – capturing and storing carbon dioxide) technology, could lead to lower CO_2 emissions into the environment[13].

Alternative energy supply

Underground coal gasification (UCG) could become an alternative with usage of deep-lying coal as a clean gasification of fuel in order to provide fuel for producing electricity. UCG for the production of gas uses and requires two or three boreholes. With two boreholes, we impress the air, oxygen or steam in the first one and as a result from the second production borehole we get gas (mainly hydrogen and carbon monoxide), which must be cleaned with special procedures for its use. Both boreholes are connected with the zone, which represents a coal block in which combustion and gasification occur, which of course is monitored and controlled. Figure 4 shows the technological scheme of the underground coal gasification using two boreholes.

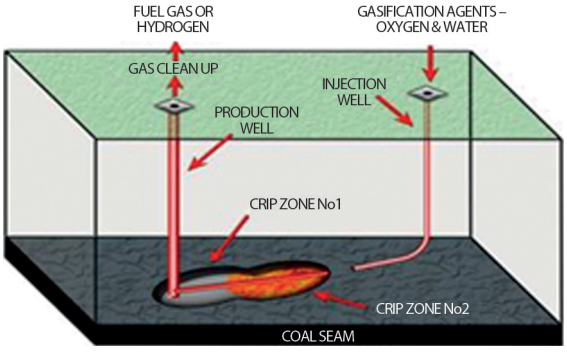

Figure 4: *Process of underground gasification with a usage of two boreholes*[14].

Figure 5 shows technological scheme of UCG with usage of three boreholes. UCG was commercially used in the former Soviet Union and Uzbekistan in the early sixties. Recent projects undertaken in China, Australia, Canada and South Africa have not led to commercial UCG projects yet. Development in these countries is oriented at improving drilling techniques and computer-aided modelling.

Results of previous studies are rather sparse in order to protect intellectual property rights. Some data has only been published on the temperature of the process, which should be higher than 1 000 °C. A discussion was held on the impact of environmental temperature on the geological formations. All the current pilot projects are estimated to be worked out in relatively small quantities of coal (15 to 20 million tons of coal), but it is likely that countries with large coal reserves will facilitate faster development of projects. UCG technology commercialization project will be extremely difficult, it will be necessary to pool knowledge and resources of interested countries, which will certainly happen in the future. This will occur fast, especially if the climate agreement is not favourable for coal.

One of the alternatives in the development of new clean coal technologies and the exploitation is gas from the coal. Methane, which is captured in the seams of coal at a great depth and layers that with an implementation of the

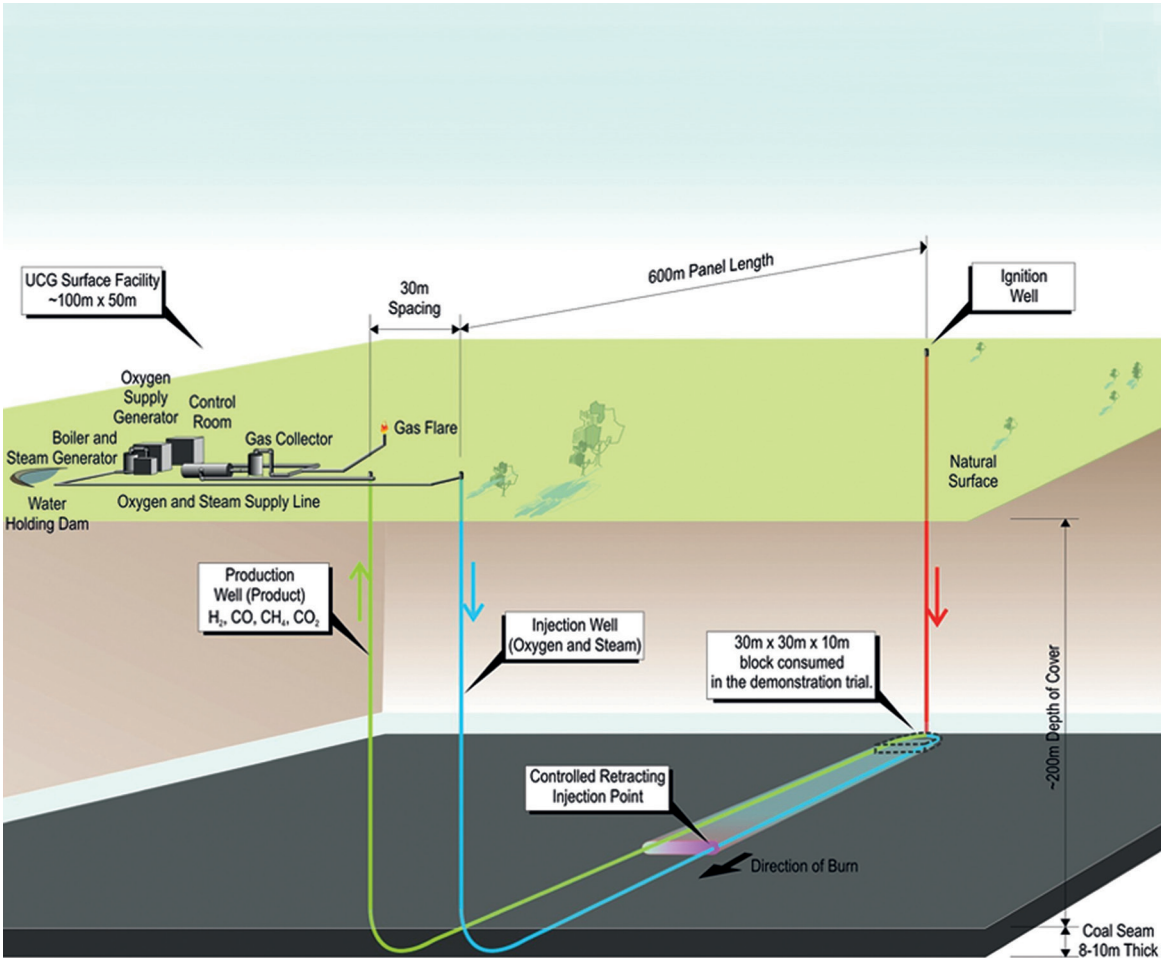

Figure 5: *Process of underground coal gasification (UCG) with a usage of three boreholes*[14].

conventional technology cannot be used, could be a potential energy resource for electricity production.

Conclusion

With domestic energy, resources in electricity production will continue to be handled in the most rational way. The fundamental objective of the Slovenian electricity sector is to maximize self-sufficiency in electricity supply[15] and use of synergy effects, building a balanced structure of energy resources in Slovenia (1/3 hydropower, 1/3 nuclear power, 1/3 thermal power). Long-term preservation of lignite mining in the Velenje coal mine is important for diversification of energy resources, particularly for electricity production. Being a domestic energy resource, it is important to reduce the risk in the energy supply. Let we remind you of 2003, when coal from Velenje was supplying 50 % of the country's electricity. That way we avoided electrical failure, which among the other countries also affected Italy. Usage of coal in block 6 in the TEŠ will be aligned with EU environmental obligations and our country will be limited to large combustion plant with high efficiency – 43 % based on BAT (best available technology) technology, and emission reduction commitments in the climate-energy package will be met in the context of the EU ETS. The remaining coal reserves in Zasavje will have a meaningful advantage in a conjunction with the investment stake in Thermal Power Plant Trbovlje, which is important for our country's energy location and will continue to be maintained. All investments in new energy facilities in Slovenia and in Europe are contributing to higher energy as environmental and economic efficiencies respectively.

References

[1] EUROCOAL - An Energy Strategy For Europe: Importance and Best Use of Indigenous Coal, Euracoal (2009). Retrieved on 9. 10. 2011, from http://www.eurocoal.org.

[2] International Energy Outlook, U. S. Energy Information Administration (2010), Washington DC 20585.

[3] World Energy Outlook, International Energy Agency, OECD/IAE (2011); Paris.

[4] World Energy Outlook, International Energy Agency, OECD/IAE (2012); Paris.

[5] Annual Report-Reserves, Resources and Availability of Energy Resources 2010 Retrieved on 9. 10. 2011 from http://www.bgr.bund.de.

[6] Medved, M., Lajlar, B. Malenković, V., Dervarič, E. (2010): Revision of coal reserves and placement of exploitation fields in exploitation of the lignite deposit in Premogovnik Velenje = Revizija rezerv premoga in umeščanje odkopnih polj pri eksploataciji ležišča lignita v Premogovniku Velenje. RMZ-Mater. geoenviron., Vol. 57, No. 2., p. 215–235.

[7] Elaborate of classification and categorization of calculated reserves in Velenje Coal Mine, December 2008, Elaborate E/09-IV.

[8] Dervarič, E. (2007): Strategija dolgoročne proizvodnje premoga in izvedba procesa prestrukturiranja Premogovnika Velenje = Strategy of the longterm coal production and the restructuring processes execution at Premogovnik Velenje. RMZ-mater. geoenviron., Vol. 54, No.3, p. 387–401.

[9] Zakon o postopnem zapiranju Rudnika Trbovlje-Hrastnik (RTH) in razvojnem prestrukturiranju regije (Uradni list RS, št. 61/2000).

[10] Vukelič, Ž., Klenovšek, B., Placer, L., Malenković, V., Dervarič, E. (2010): Geological evaluation of brown coal reserves at the Hrastnik mine - RTH, Rudnik Trbovlje-Hrastnik = Geološka evalvacija zalog rjavega premoga na območju jame Hrastnik – RTH, Rudnik Trbovlje-Hrastnik. RMZ-mater. geoenviron., Vol. 57, No. 1, p. 75–96.

[11] Dervarič, E., Malenković, V. (2005): Situation and perspectives in production of fossil fuels and the importance of the coal energy supply of the world and Slovenia. RMZ-mater. geoenviron., Vol. 52, No. 2, p. 485–493.

[12] EUROCOAL Annual Report 2010. Retrieved on 9. 10. 2011 from http://www.eurocoal.org.

[13] EUROCOAL - Guaranteeing Energy for Europe – How can coal contribute? (2010. Retrieved on 9. 10. 2011, from http://ec.europa.eu/clima/consultations/0005/registered/15188031940-74_european_association_for_coal_and_lignite_en.pdf.

[14] Safer environment (2008). Underground coal gasification (UCG) – Potential to increase coal reserve worldwide in environment-friendly manner. Retrieved on 9. 10. 2011, from http://www.google.si/search?q=underground+coal+gasification&hl=sl&biw=1280&bih=608&prmd=imvnsb&um.=1&ie=UTF-8&tbm=isch&source=og&sa=N&tab=wi.

[15] Urbančič, A. et all (2009): Zelena knjiga za Nacionalni energetski program Slovenije, Ljubljana.