

Restructuring in Slovenian coal mine

Prestrukturiranje premogovniškega gospodarstva v Sloveniji

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Abstract: Pursuant to the Energy Act, the electricity market in the Republic of Slovenia was deregulated on 1 January 2003. This completed the transition from the regulated to the market-based operation of companies including the producers as well as distributors and other entities in the power sector. The latter include the remaining operating coalmines. In order to determine the competitiveness of power generation companies and coalmines operating under deregulated electricity market conditions, various scenarios for the period 2001-2010 were developed. The objective was to define the impact of the introduction of individual mechanisms and sources of financing on the operation of the electricity market, on the competitiveness of power generation companies and, indirectly, on their business performance. In accordance with the results of the evaluation of these scenarios it was possible to identify certain measures to be implemented within the companies as well as measures to be implemented by the government in order to ensure continued stability of operation of companies in the power sector and coalmining companies following the deregulation of the electricity market.

This paper presents the process of restructuring of the only coalmine of any significance in Slovenia, which is expected to continue to operate for another 25 years. The Premogovnik Velenje coalmining company has been gearing up for the accession of Slovenia to the European Union for a number of years. In the process of defining their basic strategic business goals they have set themselves a very demanding task: no workers are to lose their jobs on account of the restructuring. The vision statement of the company clearly provides that lignite production will continue at the level ensuring efficient company operation in terms of technology as well as economy, the highest possible degree of occupational safety, humane working conditions and provision of efficient and effective solutions in relation to environmental issues arising from lignite mining.

Izvilleček: Republika Slovenija bo 1. maja 2004 postala polnopravna članica Evropske Unije, s čimer se bo v celoti zavezala pravilom, ki tudi za slovensko rudarstvo pomenijo zahtevnejše pogoje poslovanja. Slovenija je, skladno z določili Energetskega zakona, 1. januarja 2003 odprla trg z električno energijo tudi za tuje ponudnike, s čimer so dobili slovenski upravičeni odjemalci možnost nakupa električne energije v tujini. Upravičeni odjemalci so v preteklih letih porabili približno 65 % v Sloveniji proizvedene električne energije. Slovenska vlada je upravljalcu prenosnega omrežja (ELES) sicer priporočila omejitev količine električne energije iz uvoza na 20 do 25 % slovenske porabe v enem letu, vseeno pa je s tem priporočilom odprla vrata električni energiji razmeroma na široko, saj je v državah Evropske Unije le 8 % porabljene električne energije zajete v meddržavno trgovanje.

Perspektiva slovenske oskrbe z električno energijo bo v prihodnjih letih predvsem odraz dogajanj v državah Evropske Unije. Pri tem dolgoletna tradicija premogovniške dejavnosti v Sloveniji, še razpoložljive zaloge in načelo različnosti virov za proizvodnjo električne energije govorijo premožu v prid, medtem ko kvaliteta domačega premoga, stroški pridobivanja in zaskrbnjujoče globalne razmere pri emisijah CO₂, njegovo rabo močno omejujejo. Zaradi uvedbe prostega tržišča z električno energijo, bodo slovenski proizvajalci morali električno energijo proizvajati po konkurenčnih cenah, kar vključuje tudi ustrezno ceno domačih energetskih surovin. V skladu s pogledi na vlogo premoga kot energetskega vira v Evropski Uniji, strategija porabe domačega premoga temelji na ekonomičnosti, okoljevarstvenih pogojih, zanesljivosti oskrbe z energetskimi surovinami in na dejstvu, da je premog pomembna strateška surovina države. Glavna načela na področju porabe premoga so ekonomičnost (domač premog je obravnavan v okviru pravil Evropske Unije in slovenskih predpisov), ekološka ustreznost ter zanesljivost preskrbe. Ohranitev domače proizvodnje premoga je potrebna vsaj do mere, da se ohrani ustrezno znanje za primer morebitnih težav pri preskrbi z drugimi viri.

V Sloveniji aktivno delujeta le še dva premogovnika. V Rudniku Trbovlje-Hrastnik pridobivajo rjavni premog, v Premogovniku Velenje pa lignit. Za nahajališča slovenskih premogov je značilno, da jih je možno izkoriščati le podzemno. Zaradi okoljevarstvenih razlogov je raba premoga usmerjena le na termoenergetske objekte, ki imajo ustrezno rešeno tehnologijo čiščenja izpustov.

Glede na strateška načela in usmeritve Evropske Unije, bo Premogovnik Velenje v prihodnjih letih imel ob vlogi proizvajalca lignita tudi nalogo ohranjati in razširjati v dolgi zgodovini akumulirano znanje, Rudnik Trbovlje-Hrastnik pa bo v letu 2007 predvidoma končal z redno proizvodnjo.

V Premogovniku Velenje se na vstop Slovenije v Evropsko Unijo, kot tudi na liberalizacijo trga z električno energijo intenzivno pripravljajo že vrsto let. V ta namen so opredelili osnovne strateške cilje podjetja, pri čemer so si zadali izjemno zahtevno nalogo, namreč, da bodo prestrukturiranje premogovniške dejavnosti izvedli brez nasilnega zniževanja števila zaposlenih. Proces prestrukturiranja sloni na izvajanju aktivnosti za zniževanje proizvodne cene premoga, na stalnem povečevanju varnosti zaposlenih in humanosti pri izvajanju delovnih procesov ter na spoštovanju evropskih ekoloških norm.

Key words: restructuring, mine closing act, subsidies

Ključne besede: prestrukturiranje, akt o zapiranju, subvencije

1 INTRODUCTION

On 1. May 2004 the Republic of Slovenia will effectively become a fully accredited Member State of the European Union. Consequently it will also adopt the EU regulations meaning that the Slovenian coal industry will be operating under tougher conditions. In accordance with the provisions of the Energy Act, on 1. January 2003 the electricity market in Slovenia was opened to foreign suppliers thereby granting eligible customers in

Slovenia the option of purchasing electricity abroad. While the government of Slovenia has adopted the recommendation to limit the volume of imported electricity to 20–25 percent of Slovenian consumption in a single year, that recommendation has nevertheless opened the door to foreign electricity wide open as in the Member States of the European Union only 8 percent of electricity consumption is subject to interstate trade.

The future of the Slovenian power supply industry in the coming years will primarily

reflect the situation in the Member States of the European Union. The longstanding tradition of coal industry in Slovenia, remaining available deposits and the principle of multi-sourcing in relation to power generation on one side speak in favour coal, however the quality of domestic coal, costs of mining and a worrisome global situation in relation to the emissions of CO₂ on the other side represent highly limiting factors in terms of its consumption. In accordance with the established perception, in the European Union, of coal as an energy resource, the adopted consumption strategy for domestic coal is based on economic considerations, environmental requirements, resource supply reliability and on the fact that coal represents an important strategic reserve of the country. The main principles applied to coal consumption are economy (domestic coal is considered within the framework of European Union rules and Slovenian regulations), environmental acceptability and reliability of supply. Domestic coal production should be continued at least at the level required to maintain the relevant know-how in case of supply problems involving other sources.

Presently there are only two coalmines still operating in Slovenia. Brown coal is mined in the Rudnik Trbovlje-Hrastnik coalmine, and lignite in the Premogovnik Velenje coalmine. It is characteristic of Slovenian coal deposits that they only lend themselves to underground mining. Due to environmental considerations, coal consumption is limited to power generation plants equipped with appropriate facilities for the treatment of waste emissions. The Premogovnik Velenje coalmining company has been gearing up for the accession of Slovenia to the European Union, as well as for the

liberalisation of the electricity market, for a number of years. In the process of defining their basic strategic business goals they have set themselves a very demanding task, namely that the restructuring is to be implemented without forced reductions of employee numbers. The process of restructuring is based on the implementation of measures designed to lower the cost of lignite production, on continuous improvement of occupational safety and working conditions to make them more humane, and on meeting European environmental standards.

2 THE SITUATION AND ROLE OF COAL INDUSTRY IN SLOVENIA

It is a fact that in recent years the importance of mining and coalmining in the Slovenian national economy has declined significantly. Further evidence to this effect is provided when we consider the **share of coal industry in the GDP structure**, which decreased from 1.2 % in 1995 to only 0.8 % in 2001. Likewise the share of population in Slovenia with **current active professional involvement** in the coal industry has also displayed a sharp decline. In 1995, 1.0 % of active population was employed in coal industry, while in 2001 the figure was a mere 0.7 % and decreasing^[1].

2.1 Extent of Available Deposits and Quality of Coal

Only a few years ago coal was one of the primary sources for the generation of energy in Slovenia. Today it accounts for one third of total domestic power generation.

Coal deposits in Slovenia are characterised by harsh mining-geological conditions and are suitable only for underground mining. In addition, Slovenian coals also feature low energy value and poor environmental properties.

The main properties of coals in Slovenia are as follows:

- industrial brown coal: heat value 11.7 MJ/kg, ash content up to 30 %, sulphur content 2.52 %;
- industrial lignite: heat value 10.0 MJ/kg, ash content 18.5 %, sulphur content 1.43 %.

The extent of viable deposits of brown coal is 40 million tons while viable lignite deposits amount to 170 million tons. The level of lignite production in Slovenia is unlikely to undergo significant changes, however in a few years' time the mining of brown coal will be discontinued as the term provided for by legislation is set to expire in 2007. Until then, annual production will be about 600,000 tonnes. The Mine Closing Act (*Zakon za zapiranje rudnika*) also provides and evaluates the measures for future economic development of the region thereby focusing on the generation of new jobs to balance the losses of coalmining jobs, as well as on the provision of solutions in relation to social problems arising from the coalmining being discontinued.

The Premogovnik Velenje coalmine is expected to operate until 2025, i.e., until the expiry of design life of the existing power generation facilities in Šoštanj, presently the sole consumer of Velenje coal. However the coalmine itself will have to continue and complete the restructuring process started a bit over a decade ago, which means further, on-

going reductions of employee numbers while maintaining the annual level of production at approximately 3.85 million tons, keeping production costs down and an accelerated introduction of new, replacement jobs.

In the coming years Slovenia will also import coal, primarily for general consumption and industrial purposes, where, due to environmental issues, the consumption of domestic coals is objectionable and extremely limited. Imported coal will definitely become a significant source for the generation of energy supplied to Slovenian consumers, since huge deposits of high quality black coal exist on a global level and with this coal also being acceptable in terms of cost as well as from the environmental point of view. The level of imports of brown and black coal was 500,000 tons in 2000 and is expected to exceed 800,000 tons by 2010^[2].

2.2 Strategic Integration of Coalmines

One of the basic requirements for the successful business operation of the coal industry is the formation of strategic relationships, i.e. being as close as possible to customers or coal users. Since long-term contracts for the purchase of coal are not permitted in Member States of the European Union, the government of the Republic of Slovenia decided to establish the Holding Slovenske elektrarne Group, whereby it instituted a strategic integration of power generation companies and Premogovnik Velenje. The main strategic objectives of the newly established entity are as follows:

- provision of continuous supply of power and coal to Slovenian consumers;
- implementation of all core investment activities in the Slovenian power sector;

- presentation of an organized, united front of power generation companies on the market including sales on the foreign markets.

Given the fact that Holding Slovenske Elektrarne has only 1,789 MW of power at its disposal and 4,175 employees including 1,850 at the coalmine, the competitive position of the Group in comparison with much larger European power generation giants may be tenuous and subject to extensive rationalisation of operating costs. Holding has a three-member Management Board whose activities are controlled by the Supervisory Council where the power is held by the members appointed by the Slovenian government.

The Trbovlje – Hrastnik mine for the production of brown coal has a guaranteed customer in the Termoelektrarna Trbovlje power plant until 2007 and was consequently not involved in the formation of new business relationships.

2.3 Prices of Energy Sources

In the period 1991 to 1999 world prices of coal dropped by almost 30 percent, while in the long term they will remain among the most stable of all energy sources^[3].

Forecasts of world prices of energy sources^[4] estimate that the prices of oil and natural gas will be increasing while the prices of coal will be decreasing. Compared to 2002, oil prices will remain basically unchanged until 2010, by 2015 they will rise by 6 %, by 2020 by 9 % and by 2025 by 14 %.

The prices of natural gas will be increasing significantly faster, as they are expected to rise by 5 % in comparison with the base year of 2002; by 2010 they will increase by almost 20 %, by 2015 by 29 %, by 2020 by 34 % and by 2025 by 42 %.

In contrast, world prices of coal by 2005 will decrease by 3 % in comparison with 2002, by 12 % by 2010, by 14 % by 2015 and by 15 % by 2020 thus reaching the price level expected to apply until 2025^[5].

Forecast prices of energy sources for Europe differ from the forecast world prices and indicate that the prices of fossil fuels will be increasing during the entire period under consideration, i.e., 2002 – 2025.

Compared to 2002, the prices of oil are thus set to increase by 13 % by 2005, by 17 % by 2010, by 27 % by 2015, by 34 % by 2020 and by 47 % by 2025.

The prices of natural gas will be increasing even faster. By 2005 they are expected to rise by 9 %, by 2010 by 20 %, by 2015 by 37 %, by 2020 by 48 % and by 2025 by 54 % in comparison with 2002.

In the period 2002 – 2025 the price of coal is expected to post only a slight increase. Thus it should increase by approximately 1 % by 2005, by 5 % by 2010, by 6 % by 2015, by 7 % by 2020 and by approximately 8 % by 2025.

Forecast prices of energy sources for Slovenia generally match those for Europe. Buyers of electricity generated in Slovenia will continue to include primarily Slovenian consumers. Based on the data supplied by the Ministry of Environment, Spatial Planning and Energy there are 9,000 eligible users in Slovenia accounting for 65 % of total electricity consumption (eligible users are

those consumers of electricity whose rated connection power exceeds 41 kW at a single point of use). Eligible users have the option to purchase electricity abroad where prices are determined mostly on the commodity market exchanges.

Based on the data supplied by power distributors, there are over 900,000 tariff users including households, which account for a huge 70 percent of electricity consumption – for the latter the price of electricity will continue to be fixed by the government. At least until 2007, for tariff users the electricity market will be limited to domestic production.

As a rule, the prices of indigenous coal are favourably affected by the fluctuations in the price of oil, which can, primarily due to the costs of transport and handling, cause a significant rise in the price of imported coal. However the share of the cost of indigenous coal will remain prominent in the structure of the price of electricity, primarily on account of stronger environmental demands and ever increasing social problems resulting from the closing down of coalmines, reduction of production levels and industry restructuring. The present price level of domestic coal does not allow for a loss-free operation of coalmining enterprises.

2.4 Subsidies

Subsidising of the coal industry will continue in most European countries; significant resources are and will continue to be set aside in the future for the closing down of the coalmines that are dangerous and not economically viable. In accordance with the amendment to the Regulation (EC) No. 1407/

2002 of 23. July 2002, certain leading European countries in coalmining will continue to provide aid, in order maintain its own coal production, at least until 31 December 2010. Subsidies will be provided for the restructuring of the coal industry, taking into account social and regional issues as well as ensuring the required minimum quantity of indigenous coal production to guarantee access to reserves. Of the total coal consumption in the Member States of the European Union, which amounts to 247 million tons, one third is produced nationally and its mining is entirely subsidised. Subsidising of coal industry in Slovenia is subject to the Closing Down of the Rudnik Trbovlje-Hrastnik Coalmine Act (*Zakon o zapiranju v Rudniku Trbovlje-Hrastnik*).

For some years production efforts at Premogovnik Velenje have been aimed at lowering the price of coal as much as possible, without government subsidies. The price of industrial coal supplied to the TE Šoštanj coal-fired power plant by Premogovnik Velenje is subject to the Agreement between Premogovonik Velenje and Holding. It has been established that in 2002 the reference price of coal, in order to be competitive with coal imported into Slovenia, was EUR 2.8 per GJ^[2]. At Premogovnik Velenje that reference price would be achieved by producing 3.85 million tons of coal per year, which would enable the company to operate above break-even point.

2.5 Coal and Environment

Environmental protection and rehabilitation of negative impacts of mining by coalmining companies are subject to the Mining Act

(Zakon o rudarstvu) and to the provisions of the Concession Agreement whereby mining rights for the mining of coal in an economical manner were granted to them by the government.

Negative environmental impacts arising from coal processing primarily include two types of emissions: emissions of greenhouse gases and emissions of gases causing the acidity of the atmosphere (sulphur dioxide and nitrogen oxides). In the total emissions of greenhouse gases CO₂, as the product of burning fossil fuels, has a 79 % share. Mainly this is the result of coal combustion in standard thermal power plants where the emissions reach app. 1.1 kg of CO₂/kWh. With the ratification of protocols to the Convention on Long Distance Air Pollution Slovenia has adopted the international commitment in relation to the maximum total emissions of SO₂ and NO_x. For 2010, the target emissions of SO₂ for Slovenia are 27 kt or a mere 14 % of emissions in 1990, and 45 kt for NO_x, which is equivalent to 73 % of emissions in 1990.

Otherwise the use of domestic coal has been restricted to thermal power generation facilities, as the Regulation on air emissions from heating plants no longer allows the use of coals featuring the level of sulphur found in indigenous coals in combustion plants without treatment facilities.

In the Regulation imposing a levy on CO₂ there is a provision for a temporary (until 2005) partial tax and quantity tax exemption for domestic coal, which has improved the competitive position of this resource in comparison with imported coal used in power generation.

3 RESTRUCTURING OF COAL INDUSTRY IN SLOVENIA

3.1 Coal Production

The competitive imbalance between the coal mined in Slovenia (as well as in the countries of the European Union) and imported coal has forced the coal industry into a comprehensive restructuring, which however also included a reduction of production levels. Since the restructuring process has not yet been completed, the Council of the European Union adopted Council Regulation (EC) No. 1407/2002 of 23 July 2002 on State aid to the coal industry including:

- aid for the reduction of activity (for the operation of the production units that form part of a closure plan whose deadline does not extend beyond 31st December 2007);
- aid for accessing coal reserves (granted to the production units concerned to cover initial investment costs or as current production aid); and
- aid to cover exceptional costs (costs related to the environmental rehabilitation of former coal mining sites).

The above-mentioned Regulation will apply in the Member States of the European Union from 24 July 2003 until 31 December 2010. The Premogovnik Velenje coalmining company has been gearing up for the accession of Slovenia to the European Union, as well as for the liberalisation of the electricity market, for a number of years. Consequently, for several years a comprehensive restructuring has been in the process of being implemented including numerous efforts to make the core business of the company – coal pro-

duction – as cost effective as possible and to bring it to the level that would be comparable as well as competitive with coal industry in the countries of the European Union in terms of occupational health and safety, humane working conditions, environmental management and employee remuneration.

The restructuring of the ‘coalmining’ process has been defined in a way to enable the following business objectives being achieved:

- Annual productivity growth of 4 %.
- Divestment of operations not directly involved in coal mining. The adopted business strategy to this end has been for such operations to increase the share of revenue generated in the markets outside the mother company every year.
- Annual reduction of coal price by at least 2 %.
- Creation of a minimum of 40 new jobs every year.
- Ongoing modernisation of the technological process of coal production aimed at improving working conditions in the mine to make them safer and more humane.

The restructuring of Premogovnik Velenje in the recent years has produced very good results as shown in Table 1 below^[6].

Premogovnik Velenje has developed and patented its own method of excavation that enables the mining of thick layers of coal at a very high rate of productivity. The method has become well established and recognised in the world as the Velenje Mining Method. Good results have also been achieved in relation to the provision of safe and humane work practices as well as environmental rehabilitation. The number of accidents at the workplace has been reduced by more than 550 percent since 2000, and the occurrence of fires in the mine, which used to be one of the chief problems of the company as recently as fifteen years ago, has been successfully conquered by introducing quality fire prevention systems. The entire work process meets the requirements of the ISO 9001 quality certification and ISO 14001.

Table 1. Movement of significant technical parameters in the course of restructuring

	1990	1995	2000	2002	Target 2006
Production (000 t/year)	4,210	3,910	3,743	4,045	4,000
No. of employees (coalmining)	5,189	4,050	2,861	2,597	1,887
No. of employees in other companies in the Group	-	234	1,066	1,068	1,550
Total number of employees	5,189	4,284	3,927	3,665	3,437
Length of coal face (m)	716	427	302	290	375
Excavation rate (t/employee)	36.1	60.2	94.2	119.8	112.0
Productivity (t/employee/day)	3.3	4.3	5.7	6.9	9.0
Number of operational coal faces	8.4	4.5	2.7	2.2	3.0

Table 2. Movement of significant safety parameters in the course of restructuring

	1990	1995	2000	2002
Number of accidents in the mine	627	358	190	111
Number of fires in the mine	9	6	3	-
Workers on sick leave (%)	7.16	7.88	5.51	5.48

In order to improve or maintain the competitive position after the accession of Slovenia to the European Union, quite a few tasks in relation to coal mining still have to be accomplished as follows:

- a) Signing of the **agreement with Holding Slovenske elektrarne on long-term sales of lignite until 2010 for the purpose of power generation**. The price of coal has to cover the necessary expenses required for the reliable and safe operation of the coalmine.
- b) Given the strategic principles and directions of the European Union, the Republic of Slovenia has to commit to the provision that in the coming years Premogovnik Velenje, apart from its role as a lignite producer, will also assume the **key role in maintaining and broadening of know-how in relation to coalmining** accumulated over the long history of coal industry^[2].
- c) It is essential that both coalmining companies, in Velenje as well as in Trbovlje-Hrastnik, provide the necessary resources for the **continued implementation of the restructuring process**. The latter should not be interrupted and it should also be ensured that people are not forced to leave their jobs at the mother company or its subsidiaries (which have been created as a result of the restructuring of the core business activity at the coalmine – for this reason it is imperative that they continue to be subsidised for a

while yet, subject to the Programme of Gradual Adjustment to the Deregulated Market) due to the lack of resources, operational losses or lower production levels. The **Programme of Gradual Adjustment of Daughter Companies to the Deregulated Market** should be assessed and the timeframe for its implementation should also be established; it should be reviewed and adopted by management bodies in all the companies concerned.

d) **Subsidising of the Slovenian coal sector** should continue also in the coming years. While the subsidies for the operation and closing down of the Trbovlje-Hrastnik mine have been laid down by the Mine Closing Act, Premogovnik Velenje has yet to acquire the right to the subsidy, in accordance with the provisions of Regulation (EC) No. 1407/2002. The government of the Republic of Slovenia may also decide that further financing of the restructuring, closing down of coalmines and rehabilitation of infrastructure damaged by mining operations, should be managed by Holding Slovenske elektrarne. This would mean that the subsidy would be applied through the price of electricity. To this end, **appropriate rules will have to be developed** along with a model for determining the price of coal, and supervisory councils or owners of both companies will also have to provide their opinion on such documents.

e) Maintaining the existing **strategic relationship of Premogovnik Velenje and the TE Šoštanj power plant** within Holding Slovenske elektrarne is crucial for the future of coal industry in Slovenia. Slovenia has to safeguard its national interests, preserve the strategic reliability of energy supply, reduce risk in the event of extreme economic or political situations, provide an appropriate role for development in coal industry and retain the majority share in power generation companies even after its accession to the European Union.

3.2 Research and Development

Consumption of domestic coal in the coming year will continue to be restricted to the use in power generation facilities^[2]. Nevertheless, certain key issues of national importance, which for that precise reason should be co-financed by the government of Slovenia, should be addressed, as follows:

- Where and in how to **provide for the protection of potentially interesting deposits** of coal and ore, oil- and gas fields etc., in the national spatial planning legislation?
- How to define the **role of indigenous coals** after 2005 when their price will be even more severely affected by environmental pollution levies?
- Are there realistic engineering and economic options for **alternative uses of indigenous coals**? In the world we can already observe accelerated efforts to achieve significant reductions of gas emissions from coal combustion and environmental pollution due to waste (supercritical pulverised bed combustion, fluidised bed combustion, integrated coal gasification combined cycle systems, co-generation and hybrid combined cycle technologies that reduce the consumption of coal, increase its utilisation rate and reduce waste per unit of generated energy).
- Are there realistic engineering and economic options for the **elimination and disposal of CO₂** into geological and other structures of the earth crust? (The US government and the economy in the US will invest US\$ 2 billion in this area of research over the next five years.)
- Does it make sense to invest in the construction of replacement thermal power generation plants in Slovenia using **domestic waste as the energy source**, in addition to coal?
- Would it be sensible to consider the **import of foreign, low calorie and sulphur rich coals** into Slovenia for use in coal-fired power generation plants?
- Would it make sense to treat the **utility coal combustion waste (UCCW)** and subsequently process it into building materials in order to reduce the environmental impact of such waste in an economic and efficient manner? In 1999 about 50 % of electro-filter ash, 87 % of gypsum from desulphurisation treatment facilities and 100 % of dross from boilers was used as building materials in the countries of the European Union. The use of UCCW in construction industry as a replacement for building materials helps to preserve natural resources and lower emissions in the production of such materials^[7].

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