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KOMPLEKSNA PROCENA VRSTA I VISINE INDUSTRIJSKIH ŠTETA NASTALIH KAO POSLEDICA ODLAGANJA PEPELA I ŠLJAKE IZ TERMOELEKTRANA, TOPLANA I METALURŠKIH POSTROJENJA NA OBRADIVOM I DRUGOM POLJOPRIVREDNOM ZEMLJIŠTU

Izvod

Težnja ka održivom ekonomskom razvoju Republike Srbije, pokazuje izrazite potrebe za svim vidovima energije, a posebno za sve većim količinama tzv. «čiste» energije. Kako Republika Srbija preko 60% prizvodnje električne energije ostvaruje sagorevanjem velikih količina fosilnih goriva, kao nusproizvod javlja se velika količina pepela i elektranske šljake. Sem toga, velika metalurška postrojenja crne i obojene metalurgije kakva su US Steel Smederevo i RTB Bor stvaraju takođe značajne količine nesagorivih materija. Procena vrsta i visine industrijskih šteta koje nastaju na ovaj način prestavlja vrlo složen problem koji zahteva multidisciplinaran pristup. Kako bi se došlo do kvalitetnih rešenja u obzir se moraju uzeti ekološki prihvatljiva i ekonomski održiva rešenja.

Ključne reči: *Poljopoprivredna šteta, rudarska šteta, ekologija, ekonomija, održivi razvoj*

1. UVOD

Ekonomije zemalja zapadnog Balkana nalaze se u različitim fazama tranzicije i pridruživanja Evropskoj Uniji. Dinamika harmonizacije zakonodavstava i ekonomija sa odgovarajućim u Evropskoj Uniji podrazumeva primenu postupaka, procedura i standarda koje su kao preporuku Evropske komisije primenile zemlje u procesu pridruživanja u prethodnom periodu. Jedna od najvažnijih preporuka je usaglašavanje postojećih tehnologija i primena novih, sa akcentom na zaštiti životne sredine i održivom razvoju.

Većina zemalja zapadnog Balkana svoju privrednu aktivnost zasniva na eksploataciji vlastitog mineralno-sirovinskog kompleksa i razvoju izvozno orijentisane prerađivačke industrije. U ovom trenutku rastuća ekonomija Republike Srbije, pokazuje izrazite potrebe za svim vidovima energije, a posebno za sve većim količinama električne energije kao najekonomičnijem vidu pogonske energije. Kako energetika Republike Srbije preko 60% prizvodnje električne energije ostvaruje sagorevanjem velikih količina fosilnih goriva (pretežno lignita niske

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kalorične vrednosti) kao nusproizvod javlja se velika količina pepela i elektranske šljake. Sem toga, gradska naselja koja se pretežno zagrevaju daljinskim sistemom iz toplana stvaraju takođe značajne količine nesagorivih materija.

Stoga, odlaganje ovih materija koje su, kao proizvod sagorevanja, gotovo uvek, u većoj ili manjoj meri otrovne, a ne retko i sa povišenom radioaktivnošću, predstavlja ozbiljan problem, koji zahteva ekološki prihvatljiva i ekonomski održiva rešenja. Rešavanju ovog, veoma značajnog problema do sada se pristupalo u najvećem broju slučajeva parcijalno, i problem je rešavan od slučaja do slučaja. Dosadašnja iskustva u proizvodnji i preradi metala, nemetala i ugljeva, ukazala su na ozbiljnost problema odlaganja otpadnih materija na površini terena, sa svim pratećim posledicama po poljoprivredno zemljište i ukupan ekosistem kao celinu. Obzirom da se radi o godišnjim količinama od nekoliko miliona m^3 ovog materijala, koji je gotovo uvek u izvesnoj meri otrovan, a ne retko i kancerogen, pitanje njegovog odlaganja u prirodi (najčešće na poljoprivrednom zemljištu ili neposredno uz njega u blizini postrojenja u kojima se stvara) i samim tim narušavanje ukupnog ekosiste-ma mora biti tretirano sa odgovarajućom pažnjom.

Izgradnja velikih termoenergetskih kompleksa u konfliktu je sa okolinom po brojnim parametrima: zauzimanje prostora, promene reljefa, izmene ekosistema, izmeštanje stanovništva, zagađivanje vazduha, vode i zemljišta i sl. Zaštita okoline od različitih faza proizvodnje električne energije u termoelektranama je složen problem, pa i rešavanje svih pitanja iz ovog domena zahteva kompleksno sagledavanje problematike za dobijanje validnih rešenja. Treba imati u vidu činjenicu da se najveći deo električne energije kod nas dobija u termoelektranama na lignit čija je specifična potrošnja, s obzirom na kaloričnu moć vrlo velika, a problemi iskopa zbog enormnih količina jalovina, a potom pepela i šljake, posebno izraženi.

Sa druge strane rešavanje problema odlaganja ovog otpada vezano je za obradivo i drugo poljoprivredno zemljište koje se nalazi u neposrednoj blizini ovih postrojenja ili za otvorene otkopane prostore rudnika sa površinskom ili podzemnom eksploatacijom, kao potencijalno najboljim lokacijama za trajno i sigurno odlaganje ovog otpada i rekultivaciju i remedijaciju prostora.

Za procenu rizika po životnu sredinu i zdravlje ljudi, korišćene su i metode date u preporukama i uputstvima Svetske zdravstvene organizacije (WHO), Evropske fondacije za hemijsko inženjerstvo (EFCE), Agencije za zaštitu životne sredine USA (EPA-USA) i Međunarodne organizacije za rad (ILO):

- Environmental Impact Assessment of Urban Development Project, Guidelines and Recommendation, WHO, 1995;
- The Risk Assessment Guidelines, EPA Washington DC, 1986;
- Environmental Impact Assessment, McGraw-Hill International edition, Sigapores,1996;
- Major Hazard Control, WHO, Geneve, 1990;
- Metode za analizu hazarda, Tehničko uputstvo za kontrolu hazarda, Međunarodna organizacija za rad (ILO), Ženeva, 1990;
- Metode za analizu rizika, Evropska fondacija za hemijsko inženjerstvo (EFCE) Rugby, England, 1985;
- Metode za analizu hazarda, Tehničko uputstvo za upravljanje akcidentima, Washington, USA-EPA, 1989.

Inače, zavisno od hemijskog sastava, pepeo može biti podesan materijal za niz raznovrsnih namena:

1) U građevinarstvu i industriji građevinskog materijala:
   - u proizvodnji raznih vrsta opeka;
   - u proizvodnji cementa;
   - u proizvodnji betona;

- u izradi kolovoznih konstrukcija saobraćajnica;
- za temelje manjih stambenih objekata;
- u proizvodnji injekcionih masa za povećanje nosivosti zemljišta; i
- u izradi parkirališta i sportskih terena;

2) U rudarstvu:
   - kao zamena za kreč kao regulator pH vrednosti sredine u flotacijama bakra i drugih obojenih metala itd. [Monevski, Anđelković, 1989.];
   - kao zasipni material ili kao kompozitni elemenat u stvaranju različitih vrsta zasipnih mešavina [Dimovski, 2003.] u količinama koje dostižu više miliona tona.
3) U poljoprivredi:
   - za melioracije zemljišta;
   - za obogaćevinje zemljišta mikrohranivima;
   - za raziličite popravke jalovinskih zemljišta, uglavnom jalovina rudnika uglja;
   - kao polazni materijal za kompostiranje; i
   - kao delimična zamena za supstrat (kod plasteničko - stakleničke proizvodnje povrća).
4) U šumarstvu, kao podloga za gajenje.

2. EKSPERIMENTALNI DEO

Kako bi se mogla sprovesti procena vrsta i visine industrijskih šteta, kao objekti eksperimentalnih testiranja izabrani su pepelište termoelektrane Nikola Tesla u obrenovcu tzv. TENT A, i otvoreni otkopani prostori površinskih kopova rudarskog basena «Kolubara», otvoreni otkopani prostori površinskih kopova rudarsko-topioničarskog basena Bor i otvoreni otkopani prostori u Jami rudnika bakra Bor i Jami nekog od rudnika uglja sa podzemnom eksploatacijom. Industrijske štete u ovom slučaju možemo uslovno podeliti na dve grupe:

a. Poljoprivredna šteta nastala od neprimenjivanja intenzivne poljoprivredne proizvodnje određenih kultura na prostoriji namenjenoj za deponiju pepela i šljake, u period eksploatacije prostora deponije i ostale relevantne troškove izgradnje i eksploatacije deponije
b. Rudarska šteta nastala od ne otkopane raspoložive korisne mineralne sirovine, i samim time viših stopa amortizacije tehnološke opreme, takođe i oštećenja površine terena i objekata na njoj.

Kao osnova za model eksperimentalnih testiranja obrađena je, kao jedna od alternativa, tehnologija rešavanja ovog problema kroz njegovo vraćanje u utrobu zemlje, u stare otkopa. Na taj način, kako je navedeno,postigao bi se dvojaki efekat:

- dobija se dovoljna količina jeftinog, vrlo kvalitetnog zasipnog materijala, čijom primenom bi se omogućila eksploatacija onih ležišta ili njihovih delova koji do sada nisu mogli biti eksploatisani klasičnim postupcima kako sa stanovišta zaštite objekata na površini terena, tako i ergonomsko-tehničkih karakteristika tehnologije (čvrstoća ovakvog materijala, u mešavini sa drugim raspoloživim materijalima, posle ugradnje u otkope ravna je mršavom betonu posle protoka određenog vremena (3-6 meseci)),
- potpuno (ili u najvećoj meri) rešava se odlaganje ovih materija na siguran način i bez oštećenja ekološkog sistema;

Ako se ima u vidu da su ovi prostori već degradirani samom tehnologijom otkopavanja, koja nema, na sadašnjem nivou tehnološkog razvoja, tehnoekonomski opravdanu alternativu, i da je za odlaganje ovih materija na površini terena potrebna degradacija značajne površine zemljišta, onda je sa stanovišta održivog razvoja ovo jedno od prihvatljivih rešenja, ukoliko se dokaže ekonomska opravdanost.

Na ovom mestu razmotren je kompleksni tehnoekonomski model, [Dimovski, 2012.] tehnološkog rešenja vraćanja pepela i šljake iz termoelektrana, toplana i metalurških postrojenja i raznih drugih otpadnih materija u različitim vrstama mešavina u prazne prostore rudnika sa podzemnom eksploatacijom, na primeru podzemnog proizvodnog sistema u rudnom telu RT «Borska reka» u RTB Bor.

Model obuhvata više različitih međusobno integrisanih i prepletenih aktivnosti koji se u osnovi sastoji u tehnoekonomskom modeliranju:

- Postupak prikupljanja i transporta pepela i šljake do mesta ugradnje
- Pripremu i formiranje odgovarajuće zasipne mešavine
- Transport i ugradnju zasipne mešavine,
- Procena rudarske štete od ne otkopane korisne mineralne sirovine (rude bakra sa plemenitim metalima), pri čemu se stepen iskorišćenja korisne mineralne sirovine kreće oko 50%, dok ostatak ostaje u zaštitnim stubovima i pločama,
- Procena vrednosti mineralne sirovine koja se može otkopati primenom metoda otkopavanja sa ugradnjom zasipnih materijala, kada se stepen iskorišćenja korisne mineralne sirovine penje na preko 90%, i da li vrednost razlike u visini stepena otkopane rude, pokriva troškove koji nastaju ovakvim postupkom.

Vremenski horizont je, radi komparacije, usvojen na 40 godina, za šta postoje potvrđeni resursi korisne mineralne sirovine u RT «Borska reka» od preko 500 miliona tona, i za koje se vreme očekuje rad normalan elektrane sa postojećim kapacitetima i sa postojećom ili neznatno modernizovanom tehnologijom. Primenjeni model kao konstantu u svakoj od razmatranih mogućih rešenja uzima procenjenu visinu štete nastale od neprimenjivanja intenzivne poljoprivredne proizvodnje određenih kultura na prostoriji namenjenoj za deponiju pepela i šljake, u period ekploatacije prostora deponije i ostale relevantne troškove izgradnje i eksploatacije deponija po opisanom tehnološkom postupku. Kao osnovni proizvod, za ekonomsku ocenu u ekonomskom modelu figurira proizvedena električna energija, i eventualno kao dopunski program cena pepela i šljake na komercijalnom tržištu, u slučaju termoelektrana, odnosno količine proizvedenih obojenih metala i ostalih proizvoda u slučaju rudnika u koje se odlažu ove materije.

Kritični parametar izabranih rešenja praktično su troškovi transporta otpadnih materija od mesta nastanka do mesta ugradnje, koji opredeljuju koji od objekata koji stvaraju značajne količine otpadnih materija u Republici Srbiji, može gravitirati određenom mestu njegovog trajnog i ekološki prihvatljivog odlaganja. Kao metod optimizacije izabrana je metoda mrežnog planiranja, kao najpodesnija za ovu analizu.

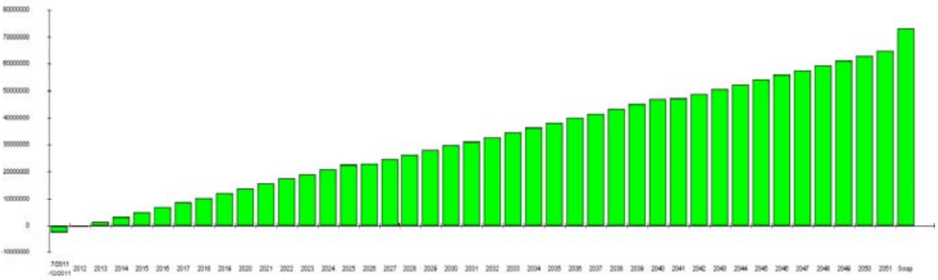
Rezultati ispitivanja dati su u narednim tabelama.

3. PRIKAZ REZULTATA

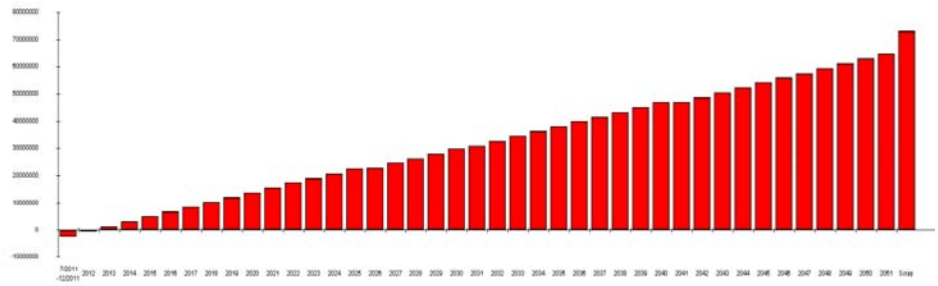
3.1. Procena poljoprivredne štete nastale od neprimenjivanja intenzivne poljoprivredene proizvodnje određenih kultura na prostoriji namenjenoj za deponiju pepela i šljake, u period ekploatacije prostora deponije i ostale relevantne troškove izgradnje i eksploatacije deponije

Kako je površina poljoprivrednog zemljišta koja je zauzeta za potrebe izgradnje deponije pepela u TENT-A procenjena na oko 500 ha, u okviru ovog dela istraživanja koja su primenjena u ovoj disertaciji, ista je podeljena na određene poljoprivredne kulture.

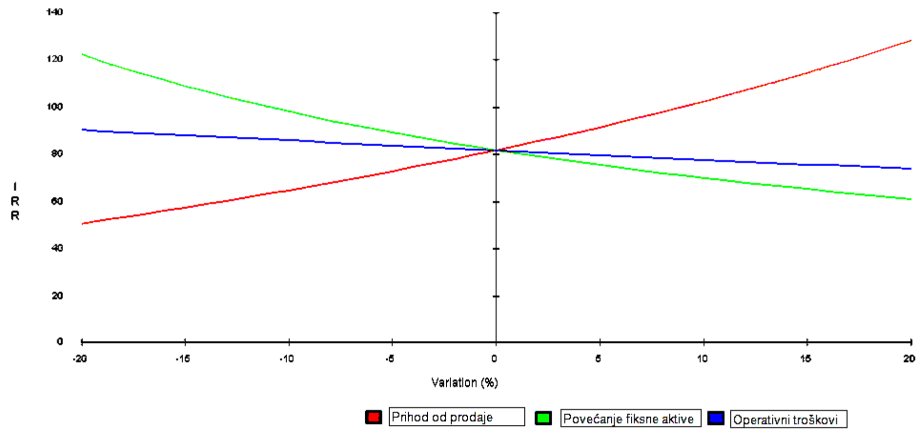
U okviru ekonomskog modela razmotrena je očekivana proizvodnja ovih kultura sa predmetnog zemljišta, tokom godina upotrebe zemljišta u druge svrhe, kako bi se mogla proceniti visina ekonomske štete. Tako je predmetna površina podeljena na 150 ha na kojima bi se sejao kukuruz, 150 ha na kojima bi se sejala pšenica, 75 ha na kojima bi se sejao krompir, 100 ha na kojima bi se sejala šećerna repa i 25 ha na kojima bi se sadi paradajz ili bi se gradili plastenici za paradajz. [Malinović i sar., 2001., Molnar i sar., 1999., Hauarnek i sar., 2001.]. Kao vremenski horizont uzeto je vreme od danas (od početka projekta) pa za 40 godina, odnosno od 2011. godine do kraja 2051. godine. Ako se ima u vidu da rad elektrane traje u kontinuitetu već 40 godina, ukoliko bi se uzele u obzir sve protekle godine, onda se vrednosti ekonomskih parametara dobijene ovom analizom mogu bez većih uopštavanja i aproksimacija udvostučiti. Rezultati modelovanja dati su u narednim tabelama i dijagramima.



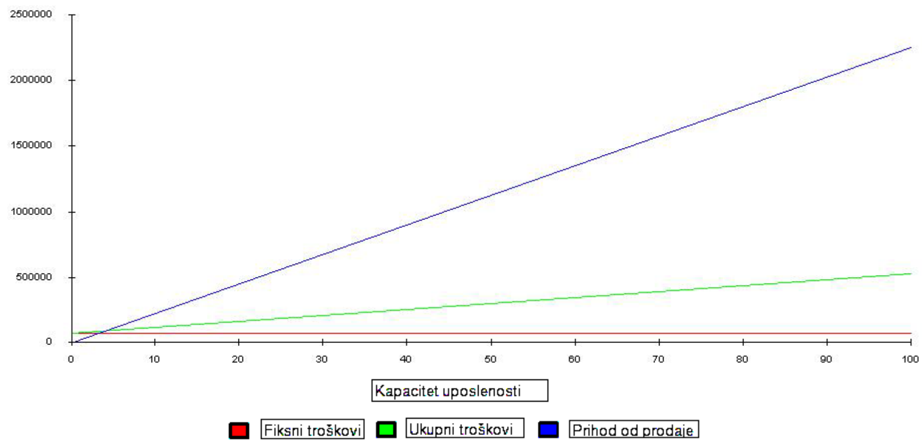
Sl. 1. *Kumulativni «keš flow» za finansijsko planiranje (u evrima)*



Sl. 2. *Kumulativni diskontovani «keš flow» za uslove normalnog povraćaja uloženih sredstava (u evrima)*



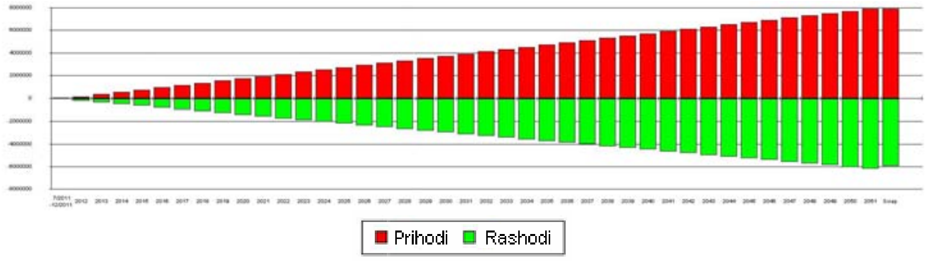
Sl. 3. *Dijagram osetljivosti interne stope povraćaja uloženih sredstava (u evrima)*



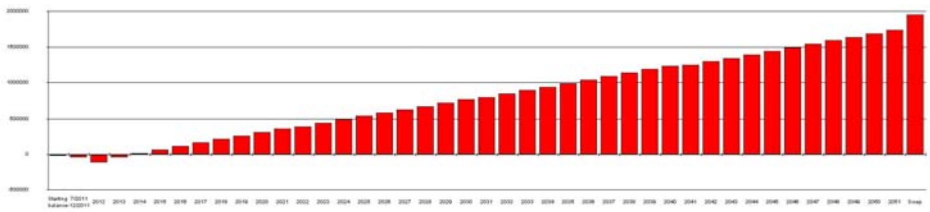
Sl. 4. *Analiza kritične tačke projekta sa uključenim troškovima finansiranja 2013 (u evrima)*

3.2. Procena ekonomskih parametara primene postupka odlaganja pepela i šljake iz termoelektrana, toplana i metalurških postrojenja vraćanjem istih «na mesto nastanka» odnosno u prostore napuštenih rudnika

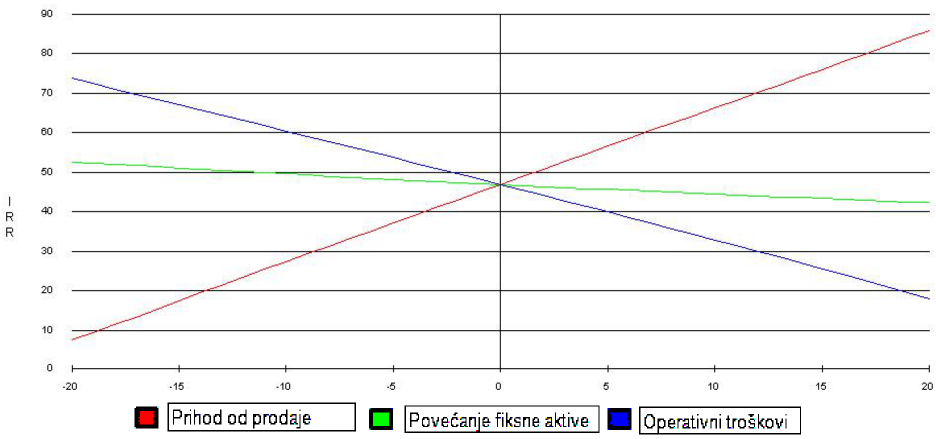
Kako je već u rado navedeno, na ovom mestu razmotren je kompleksni tehno-ekonomski model, tehnološkog rešenja vraćanja pepela i šljake iz termoelektrana, toplana i metalurških postrojenja i raznih drugih otpadnih materija u različitim vrstama mešavina u prazne prostore rudnika sa podzemnom eksploatacijom, na primeru podzemnog proizvodnog sistema u rudnom telu RT «Borska reka» u RTB Bor. Vremenski horizont je, radi komparacije, usvojen na 40 godina, za šta postoje potvrđeni resursi korisne mineralne sirovine u RT «Borska reka» od preko 500 miliona tona, i za koje se vreme očekuje rad normalan elektrane sa postojećim kapacitetima i sa postojećom ili neznatno modernizovanom tehnologijom.



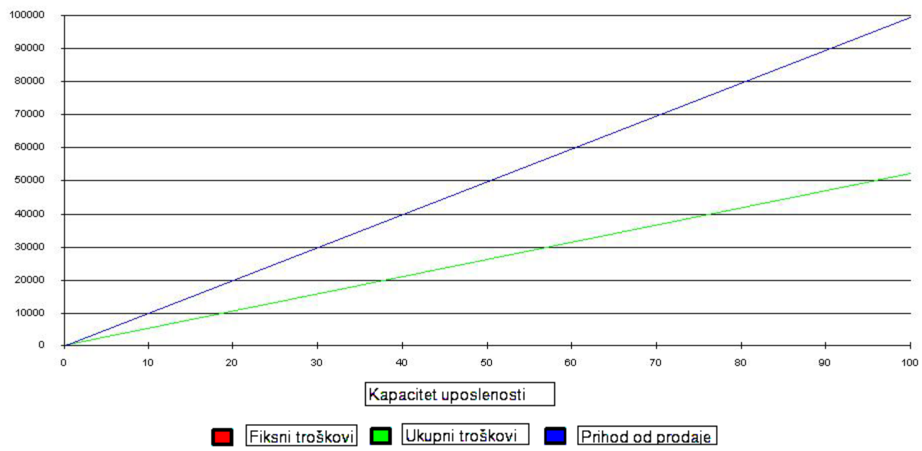
Sl. 5. *Kumulativni «keš flow» za finansijsko planiranje (u hiljadama evra)*



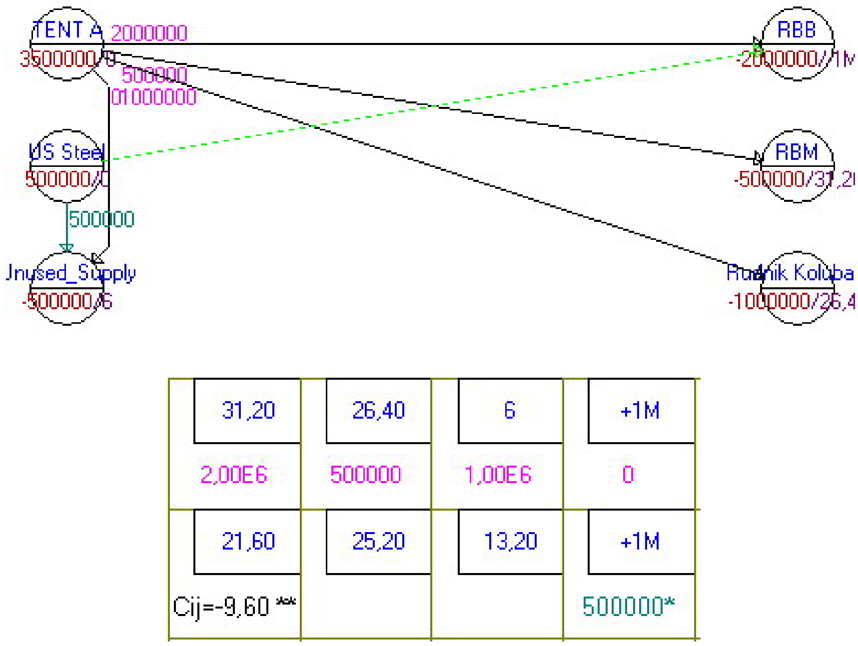
Sl. 6. *Kumulativni diskontovani «keš flow» za uslove normalnog povraćaja uloženih sredstava (u hiljadama evra)*



Sl. 7. *Dijagram osetljivosti interne stope povraćaja uloženih sredstava (u hiljadama evra)*



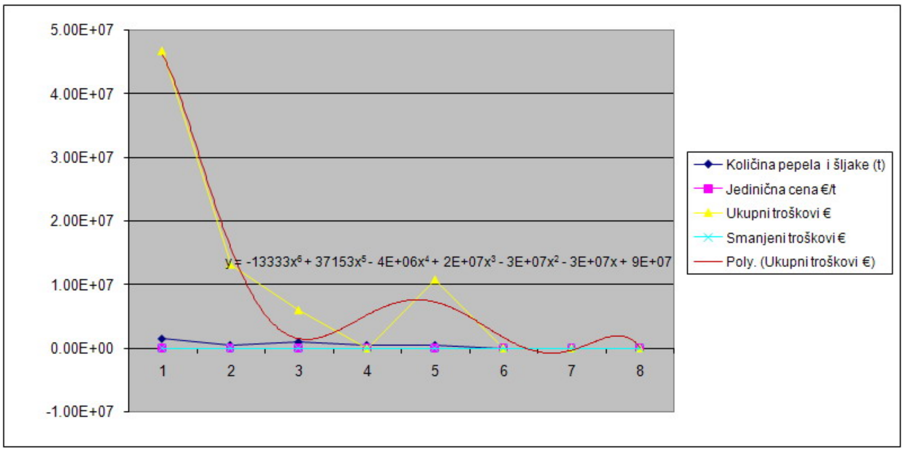
Sl. 8. *Analiza kritične tačke projekta sa uključenim troškovima finansiranja 2013 (u hiljadama evra)*



Sl. 9. *Minimizacija transportnih troškova mrežni plan*

Tabela 1. *Rešenje transporta pepela od TE do Rudnika: Minimizacija (Transportni problem)*

01-17-2012	Od	Do	Količina pepela i šljake (t)	Jedinična cena €/t	Ukupni troškovi €	Smanjeni troškovi €
1	TENT A	RBB	1.50E+06	31.2	4.68E+07	0
2	TENT A	RBM	500000	26.4	1.32E+07	0
3	TENT A	Rudnik Kolubara	1.00E+06	6	6000000	0
4	TENT A	Unused_Supply	500000	0	0	0
5	US Steel	RBB	500000	21.6	1.08E+07	0
6	US Steel	RBM	0	25.2	0	8.4
7	US Steel	Rudnik Kolubara	0	13.2	0	16.8
8	US Steel	Unused_Supply	0	0	0	9.6
	Total	Objective	Function	Value =	7.68E+07	



Sl. 10. *Minimizacija transportnih troškova dijagram*

U analizi su uzeti u obzir kao mogući «proizvođači» pepela i šljake TENT A i metulurško postrojenje US Steel iz Smedereva, a kao potencijalna mesta odlaganja Rudnici bakra Bor, Rudnik bakra Majdanpek i Površinski kopovi Kolubara u Lazarevcu. Sa dijagrama (sl. 10.) se može uočiti da su minimalni transportni troškovi primenom železničkog sistema transporta na rastojanju od 50 km i transport do 1000000 t u Kolubaru, a da je projektovanom raspodelom racionalno transportovati ovim vidom transporta 2000000 t pepela i šljake iz TENTA i 500000 t metalurške šljake iz US Steel-a u Rudnik bakra Bor.

4. DISKUSIJA

Analizom rezultata tehno-ekonomskog modela izabrani su kritični parametri modela, koji su podvrgnuti višekriterijskoj optimizaciji. Za optimizaciju korišćen je metod mrežnog planiranja.

Rezultati optimizacije predstavljeni su u tabeli 1 i na slikama br. 9 i 10. Dosadašnja istraživanja ovog problema, u prethodnom periodu, mada obimna i multidisciplinarna, nisu iz određenih razloga bila i sveobuhvatna. Pristupalo se uglavnom namenskim istraživanjima pojedinih segmenata problema, ali nikada do sada nisu uzeti u obzir i stali aspekti ove problematike. Sa jedne strane, verovatno zbog politike termoelektrana i rudarsko-metalurških kompleksa, nije se uzimala u obzir visina šteta koje nastaju ne korišćenjem poljoprivrednog zemljišta na adekvatan način. Pri razmatranju procesa odlaganja otpadnih materija iz procesa sagorevanja razmatran je samo parcijalni aspekt uticaja na životnu sredinu bez razmatranja novih mogućnosti i tehnologija zaštite, a ekonomski interes nije razmatrao i uticaj tzv. «**poljoprivredne štete»,** koja je prvi put uzeta u razmatranje u ovom radu, što predstavlja originalni pristup, za razliku od do sada primenjivanih.

Sa druge strane, nikada do sada nije ozbiljnije razmotrena mogućnost, da se odlagališta štetnih materija potpuno izmeste sa površine terena i da se ista odlože u otvorene otkope rudnika sa podzemnom (ili površinskom) eksploatacijom mineralnih sirovina, i dali vrednost dobiti od **«poljoprivredne štete»,** pokriva troškove primene ovog postupka.

Kao kruna svega u radu je obrađen tehno-ekonomski model kojim je uzeta u obzir i tzv**. «rudarska šteta»** od neotkopane korisne mineralne sirovine, čijom se kvantifikacijom i kompleksnom analizom došlo do saznanja o primenljivosti razmatrenog pristupa sa svim svojim pozitivnim efektima.

5. ZAKLJUČAK

Sa ekonomskog stanovišta, stvarni troškovi primene ovakvog sistema odlaganja, troškovi ekonomske štete od primene ove tehnologije i efekti ekoloških oštećenja su obrađeni u prethodnoj analizi. Direktna ekonomska šteta - **«poljoprivredna šteta»** od neprimenjivanja intenzivne poljoprivredne proizvodnje na prostoru koji je inače upotrebljen kao deponija, koja u do sadašnjem periodu slučajno ili namerno nije uzeta u razmatranje i analizirana na ovakav način, iznosi približno 73 miliona evra, u razmatranom periodu. Ova šteta je mnogo veća ako bi se razmotrili ostali aspekti privredne nadgradnje koji neminovno prate poljoprivrednu proizvodnju. Razmotreno tehnološko rešenje posmatrano sa tehnološkog aspekta i interesa same termoelektrane (ova konstatacija se odnosi i na metalurška postrojenja i toplane) je najmanje poželjno, jer je i najmanje razmatrano u dosadašnjem periodu.

Sa druge strane primena ove tehnologije ima dugu istoriju u rudarstvu Republike Srbije i veliki broj radova i istraživanja je sproveden iz ove oblasti. Međutim sva ova istraživanja odnosila su se isključivo na tehničko-tehnološki aspekt primene bez dubljeg ulaženja u ekološki i posebno ekonomski aspekt njihove primene. Ne bi bila preterana konstatacija da je ovakav kompleksni tehnoekonomski i ekološki pristup pionirski u ovoj oblasti, zbog nepomirljivioh razlika između «proizvođača» i «potrošača» ovih otpadnih materija i ne postojanja regulatornih tela čiji bi zadatak bio međusobna koordinacija između glavnih «stake holdersa»**.**

Primena ovog tehnološkog rešenja podrazumeva aktivnu ulogu države kao vlasnika ovih privrednih entiteta i ključnog **«stake holdersa»**. Kada se detaljno razmotri sam predlog onda se vidi da njegovom primenom svi dobijaju. Sa strane elektrane (Metalurška postrojenja i toplane) oni se trajno oslobađaju viška otpadnih materijala, osim onog dela koji se može plasirati na tržištu (cementna industrija, građevinska industrija i industrija drugog građevinskog materijala), a rudnici dobijaju «besplatno» kvalitetan pucolanski materijal koji u odgovarajućoj smeši sa granuliranom rudničkom jalovinom i jalovim peskom iz preliva hidrociklona u postrojenjima flotacije daje kvalitetan očvršćavajući zasip.

Sa stanovišta rudnika primena ovog sistema zahteva investicije u površinski kompleks za prihvat i pripremu zasipne mešavine na površini terena, podzemnog kompleksa za zasipavanje i sistema za povratne vode. Benefiti rudnika su pored eliminisanja direktne **rudarske štete** od neotkopane raspoložive korisne mineralne sirovine, i samim time viših stopa amortizacije tehnološke opreme, takođe i eliminisanje oštećenja površine terena i objekata na njoj. Investicioni trošak države odnosi se na investicije u železnički transportni sistem i železničku infrastrukturu.

Troškovi ovih investicija pokrili bi se kroz eliminisanje direktne – poljoprivredne štete i kroz eliminisanje ili smanjivanje rudarskih šteta. Sa ekološkog aspekta on je na osnovu iznetih analiza najpovoljnije rešenje jer se najveći broj uticaja na životnu sredinu u potpunosti eliminiše.

Kako je napred pomenuto, pošto se radi o značajnim investicionim ulaganjima, ukoliko bi primena ovakvih sistema zaštite bila ultimativna mera definisana određenim zakonskim propisima i pravilima (kakva važe u EU), i bila podržana od strane državnih organa i fondova Republike Srbije, stvorili bi se uslovi da se prostor Republike Srbije u potpunosti oslobodi ovih materija.

U čisto ekoonomskom smislu, ukoliko bi se posmatralo kumulativno, ukupni profit Republike Srbije iznosio bi oko **2 milijarde evra u periodu od oko 40 godina, odnosno oko 50 miliona evra godišnje**, ne računajući indirektne efekte od popravljanja stanja životne sredine, boljeg iskorišćenja raspoloživih resursa, novih radnih mesta, investicija u infrastrukturu itd.

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COMPLEX EVALUATION THE TYPE AND AMOUNT OF INDUSTRIAL DAMAGES COMMENCED AS THE CONSEQUENCE OF FLY ASH AND SLAG DUMPING FROM THE THERMO POWER PLANTS, HEATING PLANTS AND METALLURGICAL PLANTS ON ARABLE AND OTHER AGRICULTURAL LAND

Abstract

Tendency for sustainable economic development of the Republic of Serbia shows the extraordinary demands for all types of energy, and especially for increasing amounts of so called «clean» energy. Since the Republic of Serbia more than 60% of the need for energy fulfill from the thermo energy power plants with combustion of huge amount fossil fuel as the «product» remains huge amount of fly ash and slag. Beside this, the big metallurgical plants of iron, steel and stained metals like the US Steel in Smederevo and RTB Bor, also produce a significant amount of incombustible materials. Evaluation the type and amount of industrial damages commenced on the mentioned process is very complex problem which requires a multidisciplinary approach. To reach qualitative solutions, it has to be taken into consideration both ecologically acceptable and economically sustainable solutions.

Keywords: *Agricultural damage, mining damage, ecology, economy, sustainable development*

1. INTRODUCTION

Economies of the West Balkan countries are in different phases of transition and association to EU. Dynamics of harmonization of legal systems and economy with appropriate in the European Union means application of actions, procedures, and standards which are, as the recommendation of European commission, applied by the countries in the process of association informer period. One of the most important is harmonization the existing technologies and application new, with the accent on environmental protection and sustainable development.

Majority of the West Balkan countries their economic activity base on the exploitation own mineral resources complex and development export orientated processing industry. In this moment growing economy of the Republic of Serbia shows ex-

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traordinary needs for any types of energy, and especially for as higher amounts of electrical energy as the most economic type of drive power. Since the energetic industry of the Republic of Serbia more than 60% of production of electric energy realize by combustion of great amount of fossil fuels (mostly lignite coals of low caloric value) as the waste product remains high amount of fly ashes and slag. Beside this, cities, which are heating mostly from distance systems from heating plant, create also significant amounts of unburnt materials.

Therefore, waste dumping of these materials which are, as a product of combustion, almost always, more or less poisoned, and not rarely with increased radioactivity, presents serious problem, which demands ecologically acceptable and economic sustainable solutions. In solving of this, very significant problem until today was approached in the majority number of cases partially, and the problem is solved from the case to case. The existing experiences in production and processing of metals, non metals and coals, shows to the seriousness of problems of dumping the waste materials at the surface of the terrain, with all following consequences on agricultural land and ecosystem as whole. Since, that it is dealing with amounts of few million m^3 of this material, which is almost always, in certain measure poisoned, and not rarely carcinogenic, the question of its dumping in the nature (most commonly on the agricultural land or beside it in the close neighborhood of the power plant facilities where it appear) and with this interruption whole ecosystem must be treated with appropriate attention.

Construction of large thermo power complexes is in conflict with the environment for many parameters: capturing the space, changing the relief, changing the ecosystem, replacing the population, poisoning the atmosphere, water and soil etc. Environmental protection from different phases of production of electrical energy in thermo power plants is a complex problem, and so the solving of all questions from this domain demands complex approach to the problem in purpose to obtain valid solutions. It should have on mind fact that the largest part of produced electric energy in our country is made in thermo power plants which combust lignite, which specific consumption, regard to the caloric value, is very high, and the problem of excavation of enormous amount of waste rocks, and then fly ashes and slag, are especially expressed.

In the other hand solving the problem of dumping of this waste is connected with the arable and the other agricultural land which is located in the close neighborhood of this facilities or with the open caves of mines with open pit or underground exploitation, as potentially best locations for permanent and safe dumping of this waste and remediation and restoration of area.

For the prognosis of risks for living environment and health of human population, were used methods given in recommendations and guides of the World Health Organization (WHO), European Fundation for Chemical Engineering (EFCE), Agency of Environmental Protection of USA (EPA-USA) and International Labour Organization (ILO):

- Environmental Impact Assessment of Urban Development Project, Guidelines and Recommendation, WHO, 1995;
- The Risk Assessment Guidelines, EPA Washington DC, 1986;
- Environmental Impact Assessment, McGraw-Hill International edition, Sigapores,1996;
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- Methods for analyze of hazards, Technical guide for control of hazards (ILO), Geneva, 1990;
- Methods of risk analysis, European foundation for chemical (EFCE) Rugby, England, 1985;

- Methods for analyze of hazards, Technical guide for control of accidents, Washington, USA-EPA, 1989. Otherwise, depending onchemical content, ash could be suitable material for several different purposes:

1) In civil engineering and industry of civil construction materials:
   - In production of different types of bricks;
   - In cement production;
   - In concrete production;
   - In building the road constructions;
   - For the foundations of civil objects;
   - In production of injection masses for improvement of soil shipment;
   - In building parking places and sport terrains;
2) In mining:
   - As replacement of lime as regulator of pH value of pulp in the flotation plants of copper and other non ferrous metals etc. [Monevski, Andjelković, 1989];
   - As bacfilling material or as a composite element in creation of different backfilling compounds in the amounts of several million tons. [Dimovski , 2003]
3) In agriculture:
   - For soil meliorations;
   - For enrichment of soil with micro feeders;
   - For different reparations of waste land, mainly waste rocks from coal mining;
   - As the basic material in composting; and
4) In forestry as the base for raising.

2. EXPERIMENTAL PART

In purpose to realize the evaluation of type and amount of industrial damages, as the object of experimental testing is chosen waste dump of thermo power plant Nikola Tesla near the community of Obrenovac, so called TENT A, and mined out open scopes of open pits of mining basin «Kolubara», open pits of Copper Mining and Smelting Company «RTB» Bor and mined open areas of the underground mine «Jama» Bor and mined open areas in some coal mines with underground exploitation. Industrial damages in this case could be divided in two groups:

a. **Agricultural damage** from non application of intensive agricultural production at the place which is otherwise used as waste dump, in the period of exploitation the waste dump area and other relevant costs of building and exploitation of the waste dump.
b. **Mining damage** from unexploitated available mineral resources, and with this higher rate of amortization the technological equipment, also elimination the damages of the terrain surface and constructed objects on it.

As the base for model of experimental testing, one alternative was processed - technology with backfilling «at the place of origin» i.e. in the abandoned mined out areas of mines. In this way, as it is mentioned, it would be double effect:

- Obtaining sufficient amount of cheap, very good quality backfilling material, which application enables exploitation the mineral deposits or their parts which cannot be exploitable by classic mining methods, neither from the viewpoint of protection the object on terrain surface, nor from ergonomic and technical characteristics of mining technology (compressive strength of this material as mixture with other available materials, after the backfilling the open scopes is equal to the poor concrete after the time of 3-6 months,

- ❖ Completely (or mostly) is solving the dumping of this materials by safe manner and without damaging the ecological system;

Having in mind that these areas are already degraded with mining technology itself, which does not have, at the present level of technological development, a techno-economically reliable alternative, and the dumping of these materials on terrain surface demands degradation of significant area of land, then from the viewpoint of sustainable development, this is one of more acceptable solutions, if the economical reliability is proven.

At this place, a complex techno-economical mode [Dimovski, 2012] is considered of technological solution of returning fly ashes and slag from thermo power plants, heating plants and metallurgical facilities and several other waste materials in different types of mixtures in open scopes of mines with underground exploitation, in the underground mining system in the ore body «Borska reka» of the Mining and Smelting Company «RTB» Bor. Model consists of several different, mutually integrated and intertwined activities, which basically consists of techno-economical modeling:

- ➢ Procedure of collecting and transport of fly ash and slag till the place of dumping
- ➢ Processing and mixing of appropriate backfilling mixture
- ➢ Transport and fulfilling backfilling mixture
- ➢ Evaluation of mining damage from unexploitated available mineral resources (copper ore with precious metals), when the recovery ratio of available mineral resources is app. 50%, while the rest remains in pillars and roof plates,
- ➢ Evaluation of value the mineral resources which could be excavated using the mining methods with backfilling, when the recovery ratio of available mineral resources increase up to 90%, and whether value of difference in recovery ratio, cover the costs which appear in the application of such technology.

Time horizon is, in purpose of comparison, adopted for 40 years, for which the proved ore reserves exist in the ore body «Borska reka» of over 500 million metric tons, and for which the normal operation of thermo power plant is expected with existing capacities, and with existing or insignificantly improved technology. The applied models as a constant in any of considered possible solutions take the estimated amount of damage appeared from non application of intensive agricultural production of some plants on the area aimed for the waste dump, in the exploitation period of dump area and the other relevant costs of building and exploitation of dump in accordance to described technological procedure. As a basic product, for the economical appraisal the electric energy is produced in economical model and eventually as the additional program price of fly ash and slag on commercial market, in case of thermo power plants, i.e. the amount of produced non-ferrous metals and other products in case of mines where these materials are dumped.

Critical parameter of chosen solutions, practically, are the transport costs of waste materials from the place of origin to the place of dumping, which determine what objects producing the significant amount of waste materials in the Republic of Serbia can gravitate to the certain place of their permanent and ecologically acceptable dumping. As the optimization method was chosen the method of network planning, as the most suitable for such analysis. The results of modeling are shown in the following tables and diagrams.

3. PRESENTATION OF THE RESULTS

3.1. Evaluation of «agricultural damage» caused from non application of intensive agricultural production of certain cultures at the place which is aimed for fly ash and slag dump, in the period of exploitation the dump area and other relevant costs of construction and exploitation of dump

Since that the area of agricultural land which is captured, in purpose of construction the waste dump, in TENT A, is estimated to 500 ha, inside of this part of explorations which are applied in the paper, same is divided to the certain agricultural products. In the economical model, the expected production of such products is considered from experimental area, in purpose to evaluate the level of economical damage. So, the experimental area is divided to 150 ha on which corn would be sown, 150 ha for wheat, 75 ha for potato, 100 ha for beet and 150 ha for tomato the plastic tents would be built for rising the tomato [Malinović et al., 2001, Molnar et al., 1999, Hauarnek et al., 2001]. As the time horizon is a taken period from today (from the start of project) for 40 years, i.e. from 2011 to the end of 2051. Having on mind that the thermo power plant operates into continuity for 40 years, if the all passed years are taken into consideration, then the values of economic parameters could be doubled, without larger simplifications and approximations. The results of modeling are shown in the following tables and diagrams.

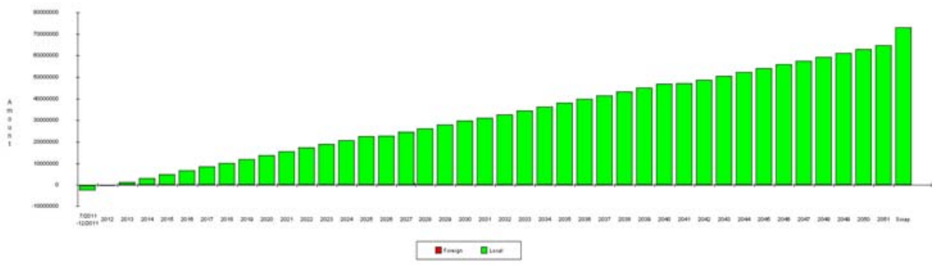


Fig. 1. *Accumulated «cash flow» for financial planning (in euro)*

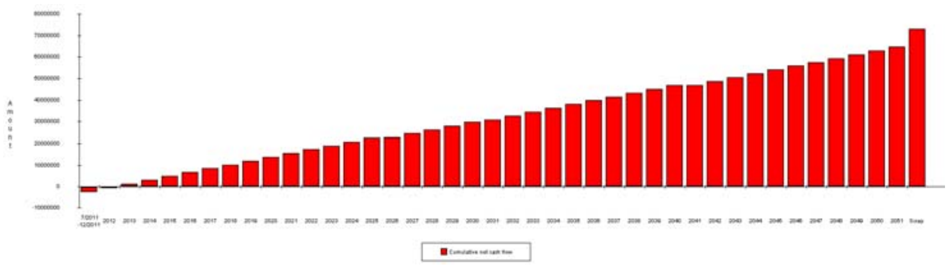


Fig. 2. *Cumulative discounted «cash flow» for normal return of investments (in euro)*

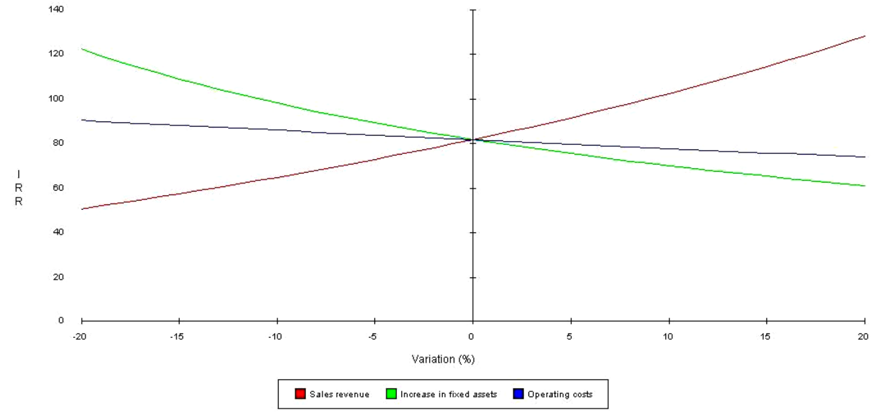


Fig. 3. *Diagram of sensitivity the internal rate of return (in euro)*

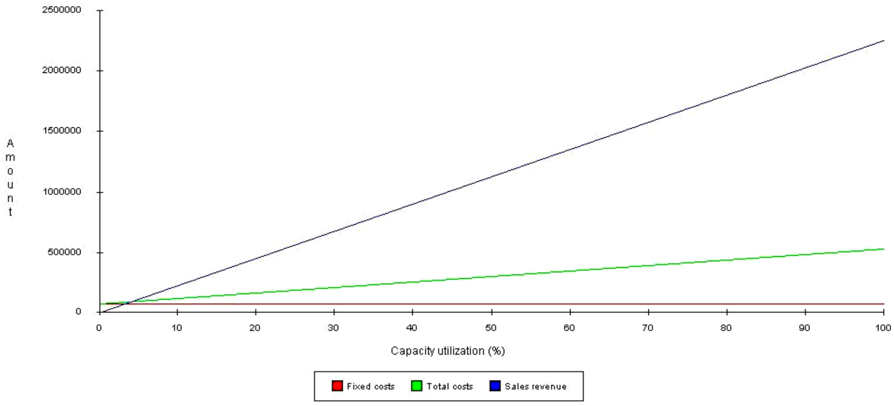


Fig. 4. *Analysis the critical point of project including costs of finance in 2013 (in euro)*

3.2. Evaluation the economic parameters of application the procedures of waste dumping of fly ash and slag from thermo power plants, heating plants and metallurgical plants with backfilling «at the place of origin», i.e. in the areas of abandoned mines

As it was already mentioned in the paper, at this place a complex techno-economical model of technological solution was considered for returning of the ash and slag from thermo power plants, heating plants and metallurgical plants and several other waste materials in different compounds in the opened caves of mines with the underground exploitation, as an example of underground mining system in the ore body «Borska reka» in RTB Bor.

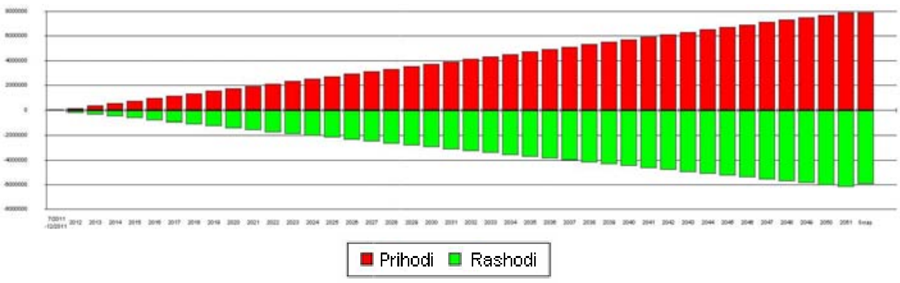


Fig. 5. *Accumulated «cash flow» for financial planning (in thousand euro)*

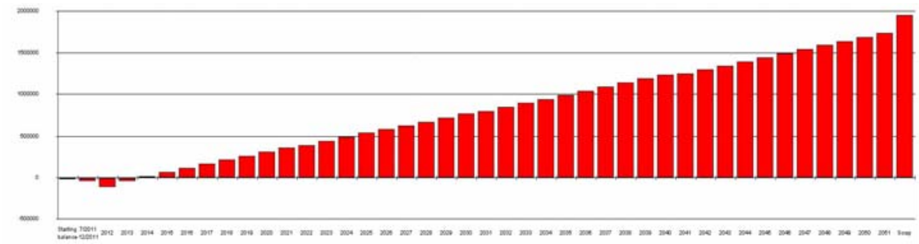


Fig. 6. *Cumulative discounted «cash flow» for normal return of investments (in thousand euro)*

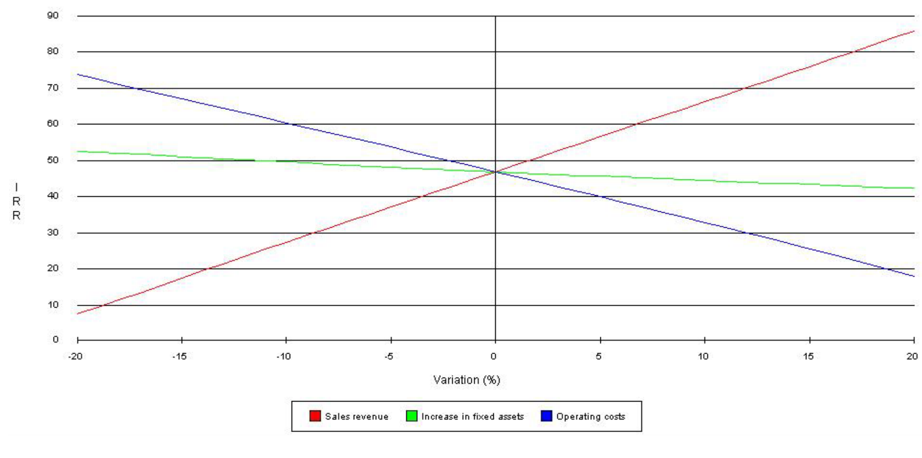


Fig. 7. *Diagram of sensitivity the internal rate of return (in thousand euro)*

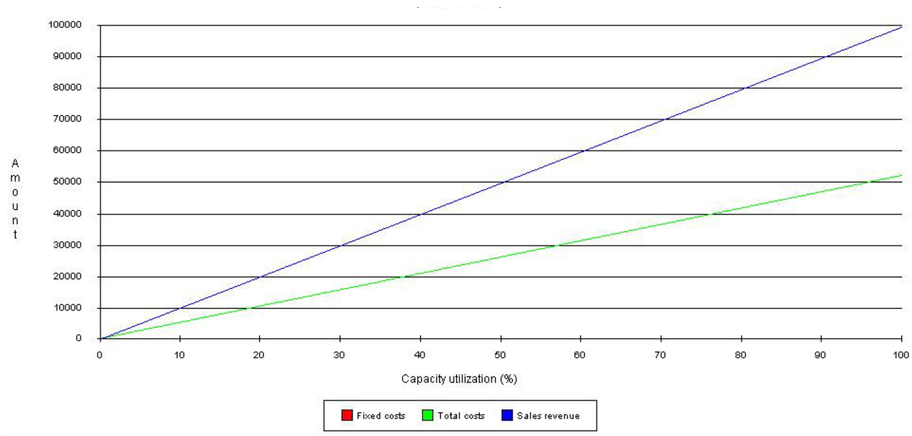
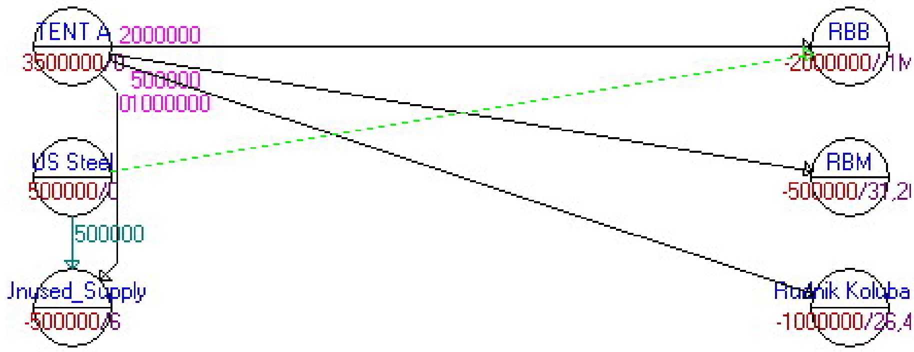


Fig. 8. *Analysis the critical point of project including costs of finance in 2013 (in thousand euro)*



31,20	26,40	6	+1M
2,00E6	500000	1,00E6	0
21,60	25,20	13,20	+1M
Cij=-9,60 **			500000*

Fig. 9. *Minimization the transport costs – Network planning*

Table 1. *Solution of fly ash transport from TPP to the Mine:. Minimization (transport problem)*

01-17-2012	Od	Do	Količina pepela i šljake (t)	Jedinična cena €/t	Ukupni troškovi €	Smanjeni troškovi €
1	TENT A	RBB	1.50E+06	31.2	4.68E+07	0
2	TENT A	RBM	500000	26.4	1.32E+07	0
3	TENT A	Rudnik Kolubara	1.00E+06	6	6000000	0
4	TENT A	Unused_Supply	500000	0	0	0
5	US Steel	RBB	500000	21.6	1.08E+07	0
6	US Steel	RBM	0	25.2	0	8.4
7	US Steel	Rudnik Kolubara	0	13.2	0	16.8
8	US Steel	Unused_Supply	0	0	0	9.6
	Total	Objective	Function	Value =	7.68E+07	

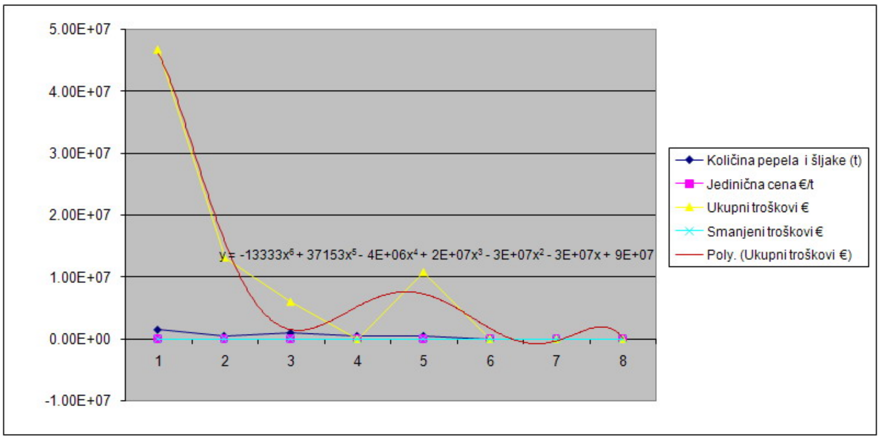


Fig. 10. *Minimization the transport costs –diagram*

Potential «producers» of fly ash and slag the TENT A, metallurgical complex US Steel from Smederevo were taken into consideration into analysis as well as the potential places of dumping the Copper Mines Bor, Copper Mine Majdanpek and Open pits of the mining Basin «Kolubara» near Lazarevac. From diagram (Figure 10), it could be noticed that minimum transport costs using the rail system of transport at distance of 50 km and transport of 1.000.000 t is in the Mining Basin «Kolubara», and that it is rational with projected distribution to transport with the same type of transporting, 2.000.000 t of ash and slag from TENT A, and 500.000 t of metallurgical slag from US Steel into the Copper Mine Bor.

4. DISCUSSION

Analyzing the results of techno-economical model, the critical parameters of model are chosen, which are treated in the multi criterion optimization. Method of network planning is used for optimization.

The results of optimization are shown in Table 1 and Figures 9 and 10. Previous explorations of this problem in former period, although voluminous and multi-discipline, where not, from some reasons universal. The approach to explorations was intended to some segments of problem, but never till now took in consideration the other aspects of problem. From one hand, probably caused by politics of management of thermo power plants and mining and metallurgical complexes, was not into the consideration amount of damage which appeared from non using agricultural land in adequate manner. In consideration of process of waste dumping from combustion process is considered only partial aspects of influence on living environment, without analyzing the new possibilities and technologies of protection, and economic interest did not also examine the influence of so called «agricultural damage», which is the first time considered in this paper, what is original approach, as the difference with previous applied.

On the other hand, never till today was not seriously examined possibility, to replace completely the waste dumps from the surface of the terrain and to be dumped in open scopes of underground (or open pit) mines, and whether the profit of **«agricultural damage»,** covers the costs of this process.

As the top of all in the paper is used the techno-economical model in which so called «**mining damages» is taken into consideration** from unexploitated available mineral resources, by which quantification and complex analysis the knowledge was gained about applicability the examined approach with all its positive effects.

5. CONCLUSION

From economic viewpoint, real costs of application of such system of dumping, costs of economic damage from application of this technology and the effects of ecological damage are treated in following analysis. Direct economic damage - **«agricultural damage»** from non application of intensive agricultural production at the place which is otherwise used as waste dump, which accidentally or with some purpose was not took into consideration and analysed in such manner, is app. 73 million euro, in the considered period. This damage is much larger if the other aspects of agricultural industrial superstructure will be considered, which inevitably follows the agricultural production.

Described technological solution considered from technological aspect and the interest of the thermo power plant itself (this statement is relate also for metallurgical facilities and heating plants) is less desirable, because it is less examined in the previous period.

On the other hand application of this technology has a long history in mining industry of Republic of Serbia and great number of papers and explorations is realized in this area. But, all of these explorations are related strictly on techno-economical aspect of application without detailed examination of ecological and especially economical aspect of their application. It wouldn´t be exaggerate the statement, that such complex techno-economical and ecological approach is pioneer in this scientific area, caused by irreconcilable differences between «producers» and «consumers» of this waste materials and absence of regulatory bodies which task would be mutual coordination between main «stakeholders».

Application of this technological solution demands the active role of state as the owner of these industrial entities as the key «stakeholders». When the problem is studied in detail then it could be found out that with this all are in profit. From viewpoint of power plants (metallurgical facilities and heating plants) they release themselves of surplus the waste materials, except the part which have market value (in cement industry, civil construction industry and the industries of several other civil construction materials), and mines obtain «free of charge» qualitative puzzolanic material which in appropriate mixture with crushed mining waste rocks and hydro flotation sand gave qualitative solid backfilling. From viewpoint of mines application of such system demands investments in surface complex for collection and preparation of backfilling mixture at the surface of the terrain, underground complex for backfilling and the system of circulating water. Benefits for mines are, beside elimination of direct «**mining damages»** from unexploitated available mineral resources, and with this higher rate of amortization of technological equipment, also elimination of damages the surface of the terrain and the objects built on it. Investments costs of the state relates on investments in rail transporting system and rail infrastructure. Costs of such investment would be covered through the elimination of direct economic damage - **«agricultural damage»** and through the elimination or reduction of «**mining damages».** From ecological aspect it is based on presented analyse most suitable solution because, usage of this solution most of influences on environment is completely eliminated.

As it is mentioned above, since it is dealing with significant investments, if the application of such systems of environmental protection would be ultimate measure defined with the certain legal regulations and rules (as they are in EU), and if they will be supported from the state and funds of Republic of Serbia, then will be created conditions for the whole territory of Republic of Serbia, to be released of this materials. In pure economical manner, if the whole problem is observed cumulatively, total profit for the Republic of Serbia would be app. **2 billion euro in period of 40 years, i.e. app. 50 million euro per year**, without taking into account the indirect effects from improvement living environment, better usage of available mineral resources, new working places, investments in infrastructure, etc.

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