UDIO TROŠKOVA RAZGRADNJE U CIJENI ELEKTRIČNE ENERGIJE IZ NE KRŠKO

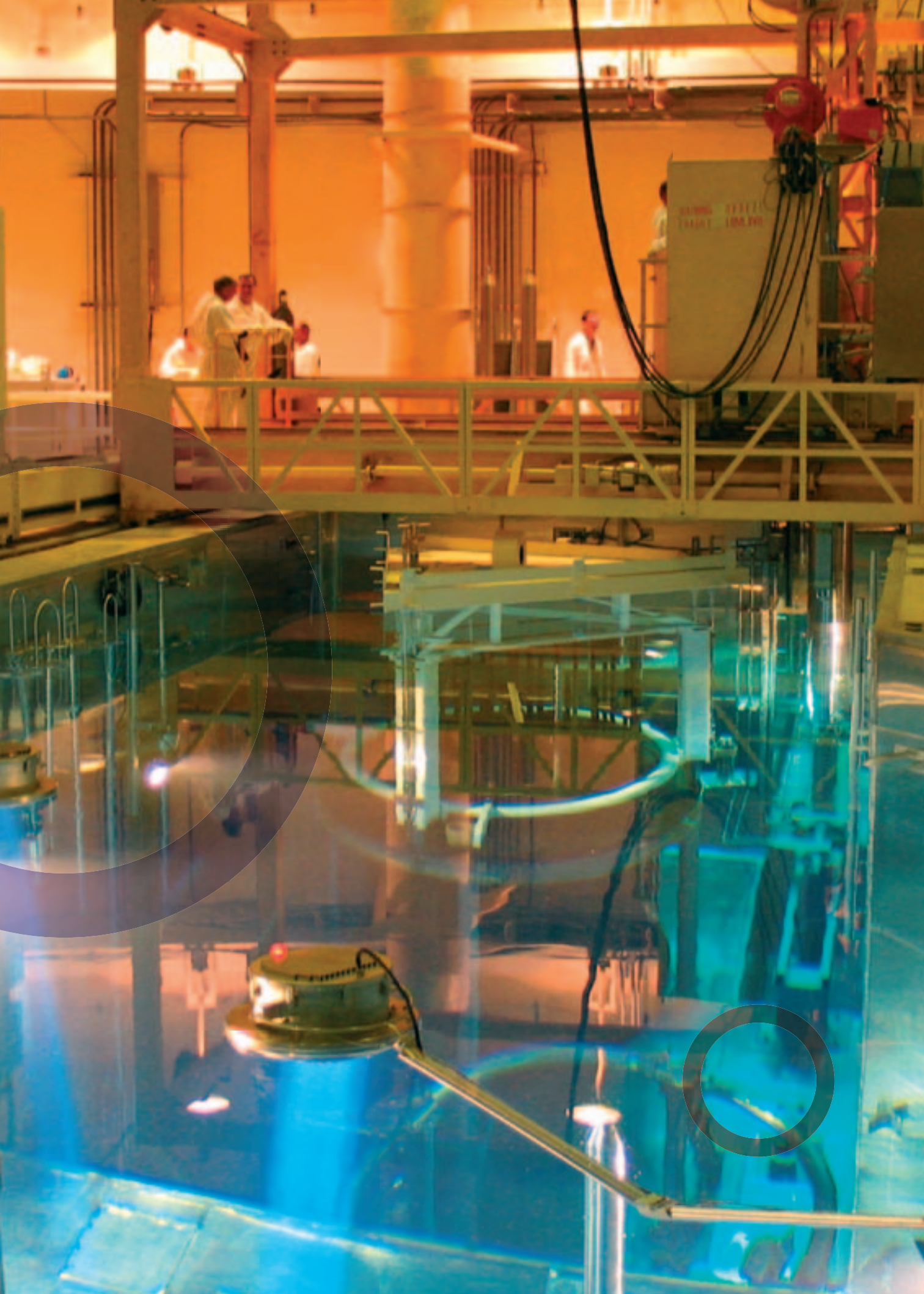
THE SHARE OF DECOMMISSIONING COSTS IN THE PRICE OF ELECTRICITY FROM THE KRŠKO NPP

Dr. sc. Vladimir Lokner, mr. sc. Damir Subašić, APO d.o.o.,
Savska 41/IV, 10000 Zagreb, Hrvatska
Ivica Levanat, dipl.ing., mr. sc. Petronila Lokner,
Tehničko veleučilište Zagreb, Konavoska 2, 10000 Zagreb, Hrvatska
Vladimir Lokner, PhD, Damir Subašić, MSc, APO d.o.o.,
Savska 41/IV, 10000 Zagreb, Croatia
Ivica Levanat, dipl. ing., Petronila Lokner, MSc, Polytechnic of Zagreb,
Konavoska 2, 10000 Zagreb, Croatia

Polazeći od Programa razgradnje NE Krško, ovaj tekst analizira potrebna hrvatska izdvajanja za troškove razgradnje u odnosu na cijenu električne energije iz te elektrane. Raspravlja se o pouzdanosti procjena Programa, a napose pretpostavljenih financijskih parametara. Radi toga je provedeno variranje diskontne stope u uobičajenom rasponu od 1 % do 5 %, kao i modela jednakih i rastućih anuiteta. Analiziraju se i hipotetički scenariji duljeg prikupljanja sredstava, jedan sličan slovenskom slučaju (opisuje što bi bilo da smo ranije počeli), dok drugi scenarij analizira moguće produljenje radnog vijeka elektrane. Posebno je raspravljen odnos financiranja kakvo preporuča Program i mjera koje su do sada poduzete za ostvarivanje tih preporuka u Hrvatskoj.

Starting from the Decommissioning of the Krško Nuclear Power Plant Program, this text analyzes the necessary Croatian allocations for the decommissioning costs in relation to the price of electricity from this power plant. The reliability of the Program estimates is analyzed, particularly the assumed financial parameters. Therefore, a variable discount rate was implemented in the customary range of from 1 % to 5 %, as well as models of equal and escalating annuities. Hypothetical scenarios were also analyzed for the long-term collection of monetary resources, similar to the Slovenian case (a description of what would have happened if we had started earlier), while the second scenario analyzes the possibility for prolonging the working lifetime of the power plant. There is also a separate discussion of the relation between the financing recommended by the Program and the measures that have been undertaken to date in order to implement these recommendations in Croatia.

Ključne riječi: fond za razgradnju, NE Krško, troškovi razgradnje
Key words: decommissioning costs, decommissioning fund, Krško Nuclear Power Plant



1 UVOD

Nuklearna elektrana Krško (NE Krško), Westinghouseovo postrojenje s jednim lakovodnim tlačnim reaktorom električne snage od oko 700 MW_e nakon nedavnih rekonstrukcija, zajedničko je vlasništvo Slovenije i Hrvatske u jednakim dijelovima. Puštena je u pogon 1982. godine, s planiranim radnim vijekom od 40 godina. Količina istrošenog nuklearnog goriva (ING) koja bi mogla nastati u planiranom radnom vijeku procijenjena je na 1 531 gorivnih elemenata ili 620 tona metalnog urana. Do kraja radnog vijeka NE Krško predviđa se da će nastati oko 3 600 m^3 tehnološkog nisko i srednje radioaktivnog otpada (NSRAO). Ako mu se pribroji i otpad koji će nastati pri razgradnji te tijekom izmjena većih komponenata, ukupna količina NSRAO koja će se nakupiti radom i razgradnjom elektrane procjenjuje se na 17 500 m^3.

Temeljem Ugovora između Vlade Republike Slovenije i Vlade Republike Hrvatske o uređenju statusnih i drugih pravnih odnosa vezanih uz ulaganje, iskorištavanje i razgradnju nuklearne elektrane Krško (Ugovor) [1], tijekom 2003. i početkom 2004. godine izrađen je zajednički Program razgradnje nuklearne elektrane Krško i zbrinjavanja nisko i srednje radioaktivnog otpada i istrošenog nuklearnog goriva (Program) [2]. Glavna svrha Programa bila je da procijeni ukupne troškove svih planiranih aktivnosti i predloži način osiguranja potrebnih sredstava. Nakon što je odobren u nadležnim tijelima obiju država (u Hrvatskoj je Sabor dao suglasnost krajem 2004. godine [3]), Program je početkom 2005. godine prihvatilo i Međudržavno povjerenstvo za praćenje provedbe Ugovora.

Razgradnja nuklearne elektrane obuhvaća sve aktivnosti potrebne za rastavljanje postrojenja, uklanjanje objekata i materijala te restauriranje lokacije tako da se dalje može koristiti kao da na njoj nije bilo elektrane. Program uz to obuhvaća i zbrinjavanje radioaktivnog otpada i istrošenog goriva (osim obrade i skladištenja u krugu elektrane za vrijeme pogona), uključujući njihovo trajno odlaganje u konačna odlagališta.

U ovome se članku termin troškovi razgradnje odnosi na ukupne troškove Programa, tj. obuhvaća i troškove razgradnje i troškove zbrinjavanja otpada i istrošenog goriva. Prema Ugovoru Hrvatska i Slovenija će financirati troškove razgradnje u jednakim dijelovima, kao što koriste i električnu energiju iz elektrane. Međutim, prikupljanje sredstava za financiranje razgradnje ne teče u obje države simetrično, jer je Slovenija još prije desetak godina osnovala svoj fond za razgradnju NE Krško.

1 INTRODUCTION

The Krško Nuclear Power Plan (Krško NPP), a Westinghouse plant with a pressurized water reactor approximately 700 MW_e following recent reconstruction, is jointly owned by Slovenia and Croatia in equal shares. It was placed in operation in the year 1982, with an anticipated working lifetime of 40 years. The quantity of spent nuclear fuel (SNF) that could be produced during the planned working lifetime is estimated at 1 531 fuel elements or 620 tons of metallic uranium. By the end of the working lifetime of the Krško NPP, it is anticipated that approximately 3 600 m^3 of low and intermediate level radioactive waste (LILW) will be produced. If to this is also added the waste that will be produced during decommissioning and the replacement of large components, the total quantity of LILW that will accumulate during the operation and decommissioning of the plant is estimated at 17 500 m^3.

Pursuant to the Contract between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on the Regulation of the Status and other Legal Issues Regarding the Investment, Exploitation and Decommissioning of the Krško Nuclear Power Plant (Contract) [1], during 2003 and in early 2004 a joint Decommissioning Program for the Krško Nuclear Power Plant and the Management of Low and Intermediate Level Radioactive Waste and Spent Nuclear Fuel (Program) was developed [2]. The main purpose of the Program was to estimate the total costs of all the planned activities and propose a manner for securing the necessary monetary resources. After the Program was approved by the authorized bodies of both countries (the Parliament in Croatia approved it in late 2004 [3]), in early 2005 it was also accepted by the Joint Commission on the Monitoring of the Implementation of the Contract.

The decommissioning of a nuclear power plant encompasses all the activities necessary for the dismantling of the plant, removing the objects and materials, and restoring the site so that it can continue to be used as if a power plant had never been located there. In addition, the Program also includes the management of radioactive waste and spent fuel (except processing and storage within the premises of the plant during its lifetime), including eventual disposal in a final repository.

In this article, the expression decommissioning costs refers to the total costs of the Program, i.e. it also includes the costs of dismantling and the costs of managing waste and spent fuel. According to the Contract, Croatia and Slovenia will be required to finance the costs of the decommissioning in equal shares, as they use the electricity from the plant. However, the monetary resources collected for financing decommissioning are not flowing symmetrically in both countries, because Slovenia already established its fund for the decommissioning of the Krško NPP ten years ago.

Sredstva za troškove razgradnje nuklearne elektrane u pravilu se osiguravaju iz cijene njezine električne energije. Što ranije tijekom radnog vijeka elektrane započne prikupljanje sredstava za razgradnju, ona će manje opteretiti tekuću cijenu električne energije. Za razgradnju NE Krško slovenska će strana do kraja predviđenog radnog vijeka prikupljati sredstva u razdoblju od 30-tak godina, dok hrvatskoj strani ostaje manje od 20 godina da prikupi jednaki iznos. Polazeći od preporuka Programa, u ovome se članku analizira udio koji će troškovi razgradnje imati u cijeni električne energije iz NE Krško u Hrvatskoj. Raspravlja se pouzdanost procjena Programa, napose pretpostavljenih financijskih parametra, a za usporedbu se analiziraju i hipotetički scenariji duljeg prikupljanja sredstava. Jedan je od njih sličan slovenskom slučaju (opisuje što bi bilo da smo ranije počeli), a drugi scenarij analizira hipotetičko produljenje radnog vijeka elektrane.

2 TROŠKOVI PREMA USVOJENOM PROGRAMU RAZGRADNJE NE KRŠKO

Program, dovršen 2004. godine završava preporukom da osnova za prikupljanje sredstava u fondove razgradnje (do iduće procjene troškova u sljedećoj reviziji Programa) bude procijenjeni ukupni trošak Programa diskontiran na 2002. godinu u zaokruženom iznosu od 350 milijuna eura, te da se sredstva koja odgovaraju tome iznosu mogu prikupiti pomoću 19 jednakih anuiteta od 28,5 milijuna eura uplaćenih od 2004. do 2022. godine u jedan hipotetički fond koji bi bio ustanovljen potkraj 2004. godine. Iz Ugovora je jasno da svaka država treba prikupiti polovicu planiranih sredstava, a formulacija o jednom hipotetičkom fondu odabrana je zato da se ne bi morala razmatrati asimetrična situacija u pogledu nacionalnih fondova za razgradnju u vrijeme izrade Programa, već je svakoj državi prepušteno da poslovanje svoga fonda prilagodi potrebnom ciljnom iznosu.

Za Hrvatsku je bila najjednostavnija opcija, sukladna preporukama Programa, da osnuje fond u koji će uplaćivati godišnje rate jednake polovici preporučenog anuiteta, tj. po 14,25 milijuna eura, počinjući od 2004. godine. U slovenskom su fondu u vrijeme izrade Programa već bila akumulirana značajna sredstva (preko 80 milijuna eura krajem 2003. godine), pa su se mogle planirati znatno manje daljnje uplate, tim više što je fond poslovao s godišnjom zaradom koja je bila daleko veća od kamate pretpostavljene u Programu.

The monetary resources to cover the costs of the decommissioning of a nuclear power plant are as a rule provided from the price of its electricity. The earlier that the collection of monetary resources begins during the working lifetime of a power plant, the less that the decommissioning costs will encumber the current price of electricity. For the decommissioning of the Krško NPP, by the end of its anticipated working lifetime the Slovenian side will have been collecting monetary resources for a period of approximately 30 years, while the Croatian side has less than 20 years remaining to collect the same amount. Starting from the Program recommendations, in this article there is an analysis of the share that the decommissioning costs will have in the price of electricity from the Krško NPP in Croatia. The reliability of the Program estimate is analyzed, particularly the assumed financial parameters, and hypothetical scenarios of longer collection of monetary funds are analyzed for purposes of comparison. One of these is similar to the Slovenian case (describing what would have happened if we had begun earlier), and another scenario analyzes the hypothetical prolongation of the working lifetime of the power plant.

2 COSTS ACCORDING TO THE PROGRAM ADOPTED FOR THE DECOMMISSIONING OF THE KRŠKO NPP

The Program, completed in the year 2004, concludes with the recommendation that the basis for the collection of monetary resources for the decommissioning fund (until the next cost estimate in the next audit of the Program) should be the estimated total cost of the Program discounted as of the year 2002 in the rounded amount of 350 million euros, and that the monetary resources corresponding to this amount can be collected through 19 equal annuities of 28,5 million euros each, to be paid from 2004 to 2022 into a hypothetical fund that would be established at the end of the year 2004. From the Contract, it is clear that each country is supposed to collect one half of the planned monetary resources, and the formulation of one hypothetical fund was chosen in order to avoid having to consider the asymmetrical situation regarding the national funds for decommissioning at the time that the Program was developed, but each country would be allowed to adjust the operations of its fund according to the target amount.

For Croatia, the simplest option, pursuant to the recommendations of the Program, was to establish a fund into which it would pay annual installments equal to one half of the recommended annuity, i.e. 14,25 million euros, starting from the year 2004.

Hrvatska, međutim, nije odmah nakon usvajanja Programa osnovala svoj fond za razgradnju NE Krško. Umjesto toga, Vlada je tek Uredbom od 28. travnja 2006. godine odredila da će Hrvatska elektroprivreda (HEP) uplaćivati godišnje iznose predviđene Programom na račun državnog proračuna, a sredstvima će upravljati Ministarstvo gospodarstva, rada i poduzetništva. Uredba uz to predviđa i osnivanje hrvatskog fonda za razgradnju NE Krško nakon donošenja zakona o fondu i prenošenje sredstava na račun fonda.

Uredbom se precizira da će anuiteti u protuvrijednosti od 14,25 milijuna eura za 2006. godinu i nadalje biti uplaćivani u jednakim kvartalnim ratama (prve dvije rate za 2006. godinu do kraja lipnja). Zaostatak za 2004. i 2005. godinu namirit će se kroz sljedećih 5 godina (računajući od kraja lipnja 2006. godine), također u jednakim kvartalnim ratama iako je Hrvatska elektroprivreda po godišnjem obračunu već rezervirala ukupni iznos zaostatka [4].

To što se sredstva do sada nisu oplođivala u fondu, prema dinamici pretpostavljenoj u Programu, podrazumijeva izvjesno povećanje kasnijih uplata, ali ono ne mora biti značajno u odnosu na korekcije koje se ionako planiraju kod sljedeće revizije Programa (a dijelom će biti i kompenzirano kvartalnim uplatama, budući da model iz Programa predviđa uplate krajem godine). No, daleko bi veći problem nastao ako se sredstva i dalje ne bi oplođivala, nego samo knjigovodstveno evidentirala u državnom proračunu. Budući da je dosta očigledno kako bi u takvom slučaju anuitete trebalo čak nekoliko puta povećati, razumno je očekivati da će hrvatski fond biti osnovan uskoro ili da će se ustanoviti ekvivalentni mehanizam oplođivanja uplaćenih sredstava. Uz tu pretpostavku, ovdje se u daljnjem razmatranju zanemaruju posljedice kašnjenja prvih uplata.

U preporukama Programa naglašava se da se predloženi iznosi izdvajanja za troškove razgradnje odnose samo na razdoblje do izrade sljedeće revizije Programa koja, prema Ugovoru, treba biti dovršena najkasnije pet godina nakon prethodne verzije Programa. Od iduće se revizije očekuje da će znatno detaljnije analizirati pojedine komponente Programa, što će rezultirati i pouzdanijom procjenom troškova. No, ne očekuje se da će se to značajnije odraziti na veličinu nominalnih troškova, ali bi promjene financijskih parametra u periodu između dviju revizija (inflacije i kamata) mogle imati znatno veći utjecaj na visinu budućih izdvajanja u fondove. Tako bi, na primjer, porast inflacije posljednjih godina mogao zahtijevati ozbiljno povećanje anuiteta, ali to ne mora značiti

In Slovenia, at the time the Program was developed, significant monetary resources had already been accumulated in the fund (over 80 million euros by the end of the year 2003), so they could plan significantly lower subsequent installments, especially because the fund was operating with an annual income that was far greater than the interest rate assumed in the Program.

Croatia, however, did not establish its fund for the decommissioning of the Krško NPP immediately after the adoption of the Program. It was not until the enactment of April 28, 2006 that the Government ordered Hrvatska elektroprivreda (HEP) to pay the annual amounts stipulated by the Program to the account of the state budget, and the monetary resources will be managed by the Ministry of the Economy, Labor and Entrepreneurship. In addition, the enactment also provides for the establishment of the Croatian fund for the decommissioning of the Krško NPP after the adoption of the Fund Act and the transfer of monetary assets to the fund account.

According to the enactment, the annuity has also been precisely specified as the kuna equivalent of 14,25 million euros for the year 2006 and will continue to be payable in equal quarterly installments (the first two installments for the year 2006 are payable by the end of June). The outstanding debt for the years 2004 and 2005 is to be settled during the next five years (calculated from the end of June 2006), also in equal quarterly installments although Hrvatska Elektroprivreda has already reserved the total amount of the outstanding debt according to its annual account [4].

Until now, these monetary resources have not accrued capital in the fund, according to the dynamics assumed in the Program, which implies a certain increase in subsequent payments, but this does not necessarily have to be significant in relation to the correction which is in any case planned during the next auditing of the Program (and will be partially compensated for by quarterly payments, since the model from the Program anticipates payment at the end of the year). However, a far grater problem would occur if the monetary funds were to continue to fail to accrue capital, not only that recorded by bookkeeping in the state budget. Since it is fairly obvious that in such a case the amount of the annuity would have to be increased several times, it is reasonable to anticipate that the Croatian fund will be established soon or an equivalent mechanism for the accruement of capital from the monetary resources paid into it. Under this assumption, in this article there will be no further consideration of the consequences of the postponement of the first payments.

i povećanje njihove relativne vrijednosti u odnosu na tržišnu cijenu električne energije.

Preporučeni anuitet za Hrvatsku prema sadašnjoj verziji Programa od 14,25 milijuna eura opterećuje cijenu električne energije iz NE Krško sa oko 0,5 EURc/kWh. Preciznije, ako se za izračun odabere proizvodnja električne energije u elektrani u protekle dvije godine, preporučeni anuiteti za hrvatski fond razgradnje mogli su se prikupiti povećanjem cijene hrvatske polovice električne energije za 0,55 EURc/kWh u 2004. godini, odnosno za 0,51 EURc/kWh u 2005. godini (tablica 1), prema podacima o proizvodnji i troškovima proizvodnje preuzetim iz godišnjih izvješća NE Krško [5].

In the Program recommendations, it is emphasized that the proposed amounts to be set aside for the decommissioning costs refer only to the period up to the preparation of the next audit of the Program, which according to the Contract is supposed to be completed no later than five years after the previous version of the Program. From the next audit, it is anticipated that there will be a significantly more detailed analysis of the individual components of the Program, which will result in a more reliable estimate of the costs. However, it is not anticipated that this will be more significantly reflected in the amount of the nominal expenditures but changes in the financial parameters in the period between the two audits (inflation and interest) could have a significantly greater impact upon the amount of the future monetary resources allocated to the funds. Thus, for example, the rise in inflation during the past years could require a serious increase in the amount of the annuities but this does not necessarily mean an increase in their relative value in relation to the market price of electricity.

The recommended annuity for Croatia according to the current version of the Program of 14,25 million euros adds approximately 0,5 EURc/kWh to the cost of electricity from the Krško NPP. More precisely, if the production of electricity in the power plant during the past two years is taken for purposes of calculation, the recommended annuity for the Croatian decommissioning fund could be collected by increasing the price of the Croatian half of the electricity by a surcharge of 0,55 EURc/kWh in the year 2004 and by 0,51 EURc/kWh in the year 2005 (Table 1), according to data on the production and production costs taken from the annual reports of the Krško NPP [5].

Tablica 1 - Proizvodna cijena električne energije iz NE Krško i dodani trošak za hrvatski fond razgradnje
Table 1 - Production costs of electricity from the Krško NPP and additional costs for the Croatian decommissioning fund

Godina / Year	Proizvodnja / Production (GWh)	Troškovi / Expenditures (10^6 EUR)	Proizvodna cijena / Production cost (EURc/kWh)	Cijena razgradnje / Decommission cost (EURc/kWh)	Udio u cijeni / Percentage of price (%)
2004.	5 212	110,25	2,12	0,55	21
2005.	5 613	113,37	2,02	0,51	20

Koliki je udio, odnosno relativni značaj toga opterećenja od 0,5 EURc/kWh u cijeni električne energije? Ako se za taj iznos uveća proizvodna cijena električne energije iz NE Krško (koja je iznosila tek malo više od 2 EURc/kWh (tablica 1), vidi se da u tako dobivenoj ukupnoj cijeni (oko 2,5 EURc/kWh) troškovi razgradnje iznose oko 20 %.

How great is the share, i.e. the relative significance of this surcharge of 0,5 EURc/kWh on the price of electricity? If this amount increases the production cost of electricity from the Krško NPP (which only amounts to somewhat more than 2 EURc/kWh, (Table 1), it is evident that the decommissioning costs amount to approximately 20 % of the total price thus obtained (approximately 2,5 EURc/kWh).

Tako visoki udio, međutim, posljedica je niske proizvodne cijene električne energije iz nuklearne elektrane koja, i nakon uvećanja za troškove razgradnje, ostaje značajno niža od prosječne proizvodne cijene električne energije u HEP-u, a napose od HEP-ovih termoelektrana. Mada sustavni eksplicitni podaci o tim cijenama nisu objavljeni, iz godišnjeg se izvješća [4] može procijeniti (oko 2,5 milijarde kuna proizvodnih troškova na 11 milijardi kWh) da je HEP-ova prosječna proizvodna cijena za 2004. godinu bila oko 3 EURc/kWh, i to pri udjelu hidroelektrana od 63 %, što znači da je proizvodna cijena termoelektrana bila barem dvostruko veća. Konkurentnost nuklearnih elektrana danas se temelji upravo na niskoj ukupnoj cijeni energije i nakon uračunatog financiranja razgradnje, odnosno potpunog uklanjanja svih korištenih objekata i materijala te otpada.

Stoga nema smisla u daljnjoj analizi promatrati izdvajanja za troškove razgradnje NE Krško kao postotak u cijeni njezine jeftine energije. Iz sličnih razloga nije osobito relevantna ni usporedba troškova s tržišnim cijenama električne energije (prema podacima European Energy Exchange [6], u proteklih se godinu dana cijena kod kontinuiranih isporuka kretala od 2,5 do 15 EURc/kWh, s prosjekom blizu 8 EURc/kWh). Ako bi se umjesto proizvodne cijene NE Krško koristila prosječna tržišna cijena, očigledno je da bi izdvajanja za razgradnju predstavljala svega nekoliko postotaka. No, ni iz takvog podatka ne može se procjenjivati je li to malo ili mnogo, jer jedini pravi kriterij predstavlja odnos ukupne cijene električne energije nuklearne elektrane prema cijeni električne energije iz drugih baznih elektrana.

Zato će se u daljnjoj analizi troškova razgradnje promatrati samo njihov apsolutni udio u cijeni električne energije koju Hrvatska dobiva iz NE Krško, tj. koliko bi EURc/kWh isporučene energije trebalo izdvojiti za financiranje anuiteta. Treba, međutim, spomenuti da HEP izdvajanja za razgradnju ne veže formalno na cijenu električne energije iz NE Krško, nego na ukupno poslovanje. Uz to, troškovi razgradnje formalno se ne uključuju u cijenu električne energije iz NE Krško ni prema Ugovoru.

Such a high percentage, however, is a consequence of the low production cost of electricity from the nuclear power plant which, even after it is increased by the decommissioning cost, remains significantly lower than the average production cost of electricity in HEP, particularly from HEP's thermoelectric power plants. Although systematically explicit information on these prices has not been published, from the annual report [4] it is possible to make an estimate (approximately 2,5 billion kunas of production costs per 11 billion kWh) so that HEP's average production costs for the year 2004 were approximately 3 EURc/kWh, of which 63 % were for hydroelectric power plants, meaning that the production costs of the thermoelectric power plants were approximately twice as high. The competitiveness of nuclear power plants today is actually based upon the low total energy cost, even after the calculated financing of the decommissioning or the total removal of all the objects and materials used, as well as the waste.

Therefore, there is no point in the further analysis of the monetary resources set aside for the costs of decommissioning the Krško NPP as a percentage of the price of its cheap energy. For similar reasons, it is not particularly relevant to compare the costs with the market costs of electricity (according to the data of the European Energy Exchange [6], which ranged in price from 2,5 do 15 EURc/kWh during the past year for continuous delivery, with an average of approximately 8 EURc/kWh). If the average market cost is used instead of the production costs of the Krško NPP, it is obvious that the monetary resources set aside for decommissioning represent only a few percentage points. However, from such data it is not possible to assess whether this is a little or a lot, because the sole genuine criterion is the relation of the total cost of electricity from nuclear power plant to the cost of electricity from other basic power generating plants.

Therefore, henceforth the decommissioning costs will be only considered as their absolute participation in the price of electricity that Croatia obtains from the Krško NPP, i.e. how many EURc/kWh of the delivered energy must be set aside in order to finance the annuities. It is necessary, meanwhile, to mention that the monetary resources that HEP is setting aside for decommissioning are not formally connected with the price of electricity from the Krško NPP, but rather with overall operations. Furthermore, the decommissioning costs are also not formally included in the price of electricity from the Krško NPP, pursuant to the Contract.

3 FAKTORI NEPOUZDANOSTI SADAŠNJE PROCJENE

Preporučeni anuiteti iz Programa temelje se na prvoj cjelovitoj procjeni troškova međusobno integriranih projekata razgradnje i zbrinjavanja otpada. Integriranje tih projekata provedeno je u nekoliko različitih scenarija koji su izloženi u završnim poglavljima Programa (gdje je proveden i obrazložen konačni izbor scenarija), a bili su i analizirani na međunarodnim radionicama i stručnim skupovima [7]. No, unatoč raznim provjerama i bez obzira na iscrpnost analiza i obrazloženja, svaka procjena, a osobito procjena troškova dugoročnih projekata, ima ograničenu točnost.

Odlučujući faktori nepouzdanosti u procjeni troškova i načina prikupljanja sredstava za ovakve programe mogu se svrstati u tri skupine:

– nepouzdanost tehničkih rješenja i njihove nominalne cijene,
– nepouzdanost modela financiranja te
– nepouzdanost u procjeni budućih društvenih i političkih okolnosti.

U ovakvim je projektima najmanja nepouzdanost tehničkih rješenja, zato što se ta rješenja temelje na tehnologijama koje su već primjenjivane ili barem dobro istražene. Nominalna cijena pojedinih radova, opreme, materijala itd. određuje se kao iznos koji bi za njih trebalo platiti u nekoj odabranoj godini kao da se tada obavljaju ili kupuju (u Programu odabrana je 2002. godina). U cijene se ugrađuju prikladni iznosi nepredvidljivih troškova, ovisno o stupnju razrađenosti projekta i poznavanja tehnologija. Tako se dobiva konzervativna procjena nominalnih cijena za koje se s razumnom sigurnošću može očekivati da obuhvaćaju sve troškove Programa.

U dugoročnim projektima daleko je veća nepouzdanost modela financiranja i njemu pridruženih parametra, zbog promjene vrijednosti novca u vremenu, koju nije moguće pouzdano predvidjeti. Opasnost od te vrste nepouzdanosti može se umanjiti konzervativnim izborom parametara, a napose redovitim revizijama programa razgradnje u kojima se parametri revidiraju prema financijskim trendovima, odnosno izračunavaju revidirani iznosi anuiteta.

Osobito je značajna nepouzdanost povezana s razvojem budućih društvenih i političkih okolnosti, zbog njihova potencijalnog utjecaja na provedbu i troškove ovakvog projekta (npr. zbog političkih usuglašavanja ili budućih raspoloženja šire javnosti svaki program razgradnje može doživjeti

3 FACTORS OF UNRELIABILITY OF THE CURRENT ASSESSMENT

The recommended annuities from the Program are based upon the first all-inclusive cost estimate of the mutually integrated projects of decommissioning and waste management. The integration of these projects has been performed in several different scenarios, which are presented in the final chapters of the Program (where the final choice of the scenario was made and explained), and they were also analyzed at international workshops and professional meetings [7]. Nonetheless, despite various types of verification and regardless of the exhaustiveness of the analysis and explanations, every estimate, particularly the estimate of the costs of long-term projects, has limited accuracy.

The deciding factors of unreliability in the estimate of costs and the manner of collecting monetary resources for such programs can be classified into the following three groups:

– the unreliability of the technical solutions and their nominal costs,
– the unreliability of the financing model, and
– the unreliability of the assessment of future social and political circumstances.

In such projects, the least unreliability is in the technical solutions, because such solutions are based upon technologies that have already been applied or are at least well researched. The nominal prices of individual tasks, equipment, materials etc. are determined as the amount that they would cost in a given year as if they were being performed or purchased then (the year 2002 was selected in the Program). The price includes suitable amounts for unforeseen expenditures, depending on the degree of the elaboration of the project and the familiarity with the technology. Thus, conservative estimates of the nominal costs are obtained, which can be expected to cover all the Program costs with reasonable certainty.

In long-term projects, there is much greater unreliability of the financing models and associated parameters due to changes in the value of money over time, which cannot be forecast reliably. The danger of such types of unreliability can be reduced by the conservative selection of parameters and especially by the regular auditing of the Program in which the parameters are audited according to the financial trends, or the revised amount of the annuity is calculated.

radikalne izmjene). Zbog nedostatka verificiranih metoda, tu vrstu nepouzdanosti nemoguće je izravno procjenjivati modeliranjem i projekcijama očekivanog razvoja. No, može se pretpostaviti da su najvjerojatnije opcije lokalnog razvoja događaja (barem u pogledu utjecaja na troškove razgradnje) uglavnom obuhvaćene rasponom relevantnih društvenih i političkih okolnosti u zemljama koje upravo provode ili su nedavno dovršile slične projekte razgradnje. Stoga nominalne cijene pojedinih komponenata programa razgradnje treba usporediti s troškovima u drugim državama. Takve usporedbe ne treba shvaćati kao provjeru pouzdanosti tehničkih rješenja (iako ponekad tako izgledaju), jer se tehnička rješenja znatno bolje mogu provjeriti analizom projekata. Razlike u nominalnim cijenama sličnih zahvata u drugim programima razgradnje prvenstveno odražavaju različite društvene, političke i gospodarske okolnosti zbog kojih su mogla ili morala biti odabrana specifična tehnička rješenja i troškovi.

3.1 Pouzdanost procjene troškova s tehnološkog stajališta

Procjena ukupnih nominalnih troškova Programa (u eurima iz 2002. godine) provedena je na temelju triju nezavisnih studija. Ovisno o detaljima poznavanja projekta, u konačni iznos uključeni su različiti iznosi nepredvidljivih troškova. Rezultati su rezimirani u tablici 2.

The unreliability in connection with the development of future social and political circumstances is of particular significance, due to the potential impact upon the implementation and costs of this project (e.g., due to political agreements or the future moods of the general public, each decommissioning program can potentially undergo radical changes). Due to the lack of verification methods, this type of unreliability is not possible to estimate directly by modeling and projections of anticipated development. However, it may be assumed that the most likely options for the local development of events (at least regarding the impact on the decommissioning costs) are generally included within the range of relevant social and political circumstances in the countries that are currently implementing or have recently completed similar decommissioning projects. Therefore, the nominal costs of the individual decommissioning program components should be compared with the costs in other countries. Such comparisons do not need to be considered as verification of the reliability of technical solutions (although they sometimes look that way), because technical solutions can be significantly better verified through project analyses. The differences in the nominal prices of similar undertakings in other decommissioning programs primarily reflect the various social, political and economic circumstances, due to which specific technical solutions and costs may have been or had to have been selected.

3.1 Reliability of cost estimates from the technological standpoint

An estimate of the total nominal costs of the Program (in euros from the year 2002) was performed, based upon three independent studies. Depending upon the detail of familiarity with the project, various amounts of unforeseeable costs are included in the final amount. The results are summarized in Table 2.

Tablica 2 – Procjena nominalnih troškova Programa razgradnje NE Krško
Table 2 – Estimate of the nominal costs of the decommissioning of the Krško NPP Program

	Odlaganje NSRAO / Disposal of LILW	Odlaganje ING / Disposal of SNF	Skladište ING / Warehousing oh SNF	Razgradnja NE Krško / Decommissioning the Krško NPP	Ukupno / Total
Procjena / Estimate (10^6 EUR)	186	568	189	206	1 149
Nepredvidljivi trošak / Unforeseeable cost (%)	10	30	10-15		21

Procjena troškova odlaganja NSRAO izvršena je na temelju detaljnog projekta pripovršinskog odlagališta tunelskog tipa, koje je konzervativno odabrano umjesto jeftinijeg površinskog tipa, pa su u konačni iznos uračunati nepredvidljivi troškovi od samo 10 %.

Za odlaganje ING, u Programu je izrađen samo idejni koncept prema švedskoj tehnologiji. U izradi koncepta i procjeni troškova sudjelovali su švedski stručnjaci i eksperti IAEA. Budući da projekt tek treba detaljnije razraditi u idućim iteracijama Programa, u troškove odlaganja ING uračunati su nepredvidljivi troškovi od 30 %.

Troškovi razgradnje postrojenja elektrane, te suhog skladištenja ING prije odlaganja, izračunati su na temelju analize i prilagodbe ranije studije koju je izradila njemačka tvrtka NIS Ingenieurgesellschaft GmbH [8]. Cijene iz njemačke studije (USD iz 1995. godine) preračunate su u eure iz 2002. godine, uz obračun inflacije prema rastu cijena industrijskih proizvoda u Njemačkoj, a potom su izvršene korekcije koje su uključivale i nepredvidljive troškove. Najprije su udvostručeni troškovi radne snage (blizu 60 % ukupnog troška), koji su u studiji NIS bili ozbiljno podcijenjeni jer su odražavali tadašnje zaostajanje lokalnih nadnica za europskim. Zatim su svi ostali iznosi uvećani za nepredvidljive troškove od 50 %, osim cijena spremnika za ING kod kojih je kao primjereniji odabran nepredvidljivi trošak od 20%. Zbog nepotpunog razdvajanja nekih aktivnosti razgradnje i suhog skladištenja ING (osobito pripremnih), u razgraničenju troškova ima manjih nepreciznosti, a udio nepredvidljivih troškova u ukupnim iznosima je između 10 i 15 %. Za iduću iteraciju Programa predložena je *ab ovo* izrada razgraničenih studija razgradnje postrojenja i skladištenja ING.

U ukupnim nominalnim troškovima Programa ukupni nepredvidljivi iznosi čine malo više od 20 %. To je i vjerojatna gornja granica iznosa za koji bi nominalni troškovi mogli biti precijenjeni. Ne može se, dakako, isključiti ni mogućnost da će nepredvidljivi troškovi biti doista utrošeni, kao niti da su podcijenjeni. Nije, međutim, nimalo vjerojatno da bi procjena nepredvidljivih troškova mogla biti višestruko manja od stvarno potrebnih; u najgorem slučaju, stvarno potrebni izdaci možda bi se mogli, zbog nepreciznosti projekata i nepotpunog uvida u moguće troškove tehnološke realizacije, približiti dvostrukom iznosu procjene nepredvidljivih troškova u Programu. Stoga se može s velikom sigurnošću tvrditi da je, s tehnološkog stajališta, pouzdanost procjene ukupnih troškova unutar granica od 20 %. U prilog ovakvoj ocjeni idu i činjenice da je u analizi

The estimate of the costs for the disposal of LILW was performed based upon a detailed project for a tunnel-type near-surface repository, which was conservatively selected instead of a less expensive surface type, so that only 10 % of the unforeseen costs are calculated in the final amount.

For the disposal of SNF, only the basic concept has been prepared according to Swedish technology in the Program. Swedish professionals and experts from the International Atomic Energy Agency (IAEA) participated in the preparation of the concept and cost estimate. Since the project requires more detailed work in the future iterations of the Program, the costs of SNF disposal include unforeseen expenditures of 30 %.

The costs of the decommissioning of the existing nuclear power plant and the dry warehousing of SNF prior to disposal are calculated on the basis of the analysis and adaptation of earlier study that was prepared by the German firm of NIS Ingenieurgesellschaft GmbH [8]. The costs from the German study (1995 USD) were converted into 2002 euros, with inflation calculated according to the increases in the cost of industrial products in Germany, after which corrections were performed that also included unforeseen expenditures. First of all, the costs for labor were doubled (nearly 60 % of the total cost), which in the NIS study were seriously underestimated because they reflected the local wages at the time, which lagged behind European wages. All the other amounts were then increased by unforeseen costs of 50 %, except the price of containers for the SNF, which were increased by 20 % for unforeseen expenditures. Due to the incomplete separation of some of the decommissioning activities and dry warehousing of the SNF (especially preparatory), in the determination of the expenditures there is minor imprecision, and the share of unforeseen expenditures in the total amounts is between 10 % and 15 %. For the next iteration of the Program, the *ab ovo* preparation of separate studies for the decommissioning of the plant and the warehousing of the SNF is proposed.

In the total nominal costs of the Program, the total unforeseen amounts comprise slightly over 20 %. This is most probably the upper limit of the amounts by which the nominal costs could be overestimated. The possibilities certainly should not be excluded that unforeseen expenditures will actually be incurred or that they are underestimated. It is not, however, even slightly probable that the estimate of the unforeseen costs could be several times lower than actually required. In the worst case, the actually necessary expenditures could perhaps, due to the lack of precision of the project and incomplete insight into the potential costs of

projekata i procjeni troškova Programa sudjelovalo nekoliko ekspertnih misija IAEA, te da je Program dobio pozitivnu ocjenu neovisnog recenzenta, tvrtke EDF (Electricite de France).

Usporedba s troškovima sličnih projekata u drugim zemljama nije u ovoj reviziji Programa provedena na tako sustavan način da bi se mogla uporabiti za raspravu o nepouzdanosti procjene koja bi proizlazila iz raspona mogućih društvenih, političkih i gospodarskih okolnosti. Stoga bi bilo potrebno pažljivo odabrati usporedive elemente troškova, kompenzirati razlike u načinima obračuna i valutama, te analizirati uzroke zbog kojih se tako revidirani iznosi razlikuju. Umjesto toga, u završnom poglavlju Programa samo su prikazani rasponi troškova iz dostupnih kompilacija, što se ovdje ukratko rekapitulira (uz zanemarivanje male razlike između eura i dolara 2001. godine).

Raspon cijena izgradnje odlagališta NSRAO (preračunat na jediničnu količinu odloženog otpada) prikazan je prema poznatoj studiji Agencije za nuklearnu energiju NEA [9]. On varira, otprilike, od 150 USD/m^3 do preko 7 000 USD/ m^3. U cijenu na jedinicu odloženog otpada nisu uračunati troškovi izbora lokacije te troškovi godišnjeg pogona. U slučaju tunelskog odlagališta NSRAO iz Programa, ta cijena bi iznosila oko 3 800 EUR/m^3, tj. bila bi bliže gornjoj granici navedenog raspona.

Procjena troškova razgradnje postrojenja NE Krško uspoređena je s podacima iz studije OECD/NEA [10] za 11 PWR elektrana. Srednja vrijednost troškova razgradnje tih elektrana iznosi 350 EUR/kW_e uz standardnu devijaciju od 185 EUR/kW_e. Troškovi scenarija za NE Krško koji je usvojen u Programu iznose oko 250 EUR/kW_e, što znači da su ispod srednje cijene, ali unutar raspona vrijednosti izvedenih za slične elektrane.

Troškovi za suho skladištenje ING načelno su analizirani u preliminarnoj nezavisnoj studiji o zbrinjavanju ING [11]. Ona je ukazala na poteškoće preračunavanja između različitih projekata, te usporedila scenarij skladištenja ING iz Programa (189 milijuna eura) s ukupnim troškovima nizozemskoga primjera (za skladištenje ING u istom periodu iznosili bi oko 218 milijuna eura), što pokazuje da između ta dva projekta nema značajnih razlika u troškovima.

I procjena troškova odlaganja ING uspoređena je s jednom kompilacijom OECD/NEA [12] koja ukazuje na veliki raspon cijena. Navedene procjene troškova po jedinici količine otpada variraju od 80 000 do 1 200 000 EUR/t metalnog urana, pri čemu niže cijene po jedinici količine

the technological solutions, be close to twice the amount of the estimated unforeseen expenditures in the Program. Therefore, it can be asserted with great certainty that from the technological standpoint, the reliability of the estimate of the total costs is within a limit of 20 %. In support of such an estimate are the facts that several expert missions from the IAEA participated in the project analysis and cost estimate, and that the Program received a positive evaluation from an independent reviewer, the firm of Électricité de France (EDF).

Comparison with the costs of similar projects in other countries was not performed in this audit of the Program in such a systematic manner that could be used for the discussion of the unreliability of the estimate due to the range of the potential social, political and economic circumstances. Therefore, it would be necessary to select the comparative elements of expenditures carefully, compensate for the differences in the manner of the statement of accounts and foreign currencies, and analyze the causes due to which such audited amounts differ. Instead of this, in the concluding chapter of the Program only the ranges of expenditures from the available compilations are presented, which are recapitulated here briefly (ignoring the small differences between the euro and dollar in the year 2001).

The range of the costs of constructing a repository for LILW (calculated per unit measure of disposed waste) is presented according to the well-known study by the Nuclear Energy Agency (NEA) [9]. It varies, approximately, from 150 USD/m^3 to over 7 000 USD/m^3. The costs of location selection and the annual operation costs are not calculated in the cost per unit of disposed waste. In the event of a tunnel repository for the LILW from the Program, this expenditure would amount to 3 800 EUR/m^3, i.e. it would be closer to the upper limit of the aforementioned range.

The estimate of the decommissioning costs of the Krško NPP is compared with the data from an OECD/NEA study [10] for 11 PWR power plants. The average value of the decommissioning costs for these power plants amounts to 350 EUR/kW_e, with a standard deviation of 185 EUR/kW_e. The cost scenario for the Krško NPP that was adopted in the Program amounts to approximately 250 EUR/kW_e, which means that the costs are below the average but within the value range for similar power plants.

Costs for the dry warehousing of SNF were in principle analyzed in a preliminary independent study on SNF managemen [11]. It demonstrated the difficulties of conversion between different projects and compared the scenario for the warehousing of SNF from the Program (189 million euros) with the total costs of the

otpada u pravilu iskazuju države koje imaju veće količine goriva. Cijena odlaganja ING iz Programa (916 000 EUR/t), sukladno tome pravilu, nalazi se blizu gornje granice navedenog raspona.

U cjelini gledano, citirane usporedbe više doprinose dojmu realističnosti procjene ukupnih troškova Programa, nego što omogućuju ocjenu njihove nepouzdanosti zbog mogućeg razvoja društvenih i političkih okolnosti.

3.2 Fiskalna pouzdanost procijenjenih uplata

Da bi se odredilo kolike anuitete treba uplaćivati u nacionalne fondove, u Programu je odabran jednostavan i transparentan financijski model. Njegovu je pouzdanost lako analizirati, kao i korigirati iznos daljnjih anuiteta u slučaju znatnijih promjena kamatne i inflacijske stope.

Nominalni troškovi svih aktivnosti Programa, određeni u cijenama na kraju 2002. godine, najprije su raspoređeni prema vremenskom planu po godinama u kojima će se radovi izvoditi (pretpostavlja se plaćanje na kraju svake godine). Potom je svaki nominalni trošak, iz godine u kojoj je planiran, diskontiran na početni trenutak, tj. na kraj 2002. godine. Zbrajanjem svih diskontiranih iznosa dobiven je ukupni diskontirani trošak Programa. On odgovara iznosu koji bi, da se od 2002. godine oplođuje (ukamaćuje) u nekom fondu, bio dovoljan za financiranje svih budućih troškova Programa kojima će cijena u međuvremenu narasti zbog inflacije (u odnosu na nominalne cijene iz 2002. godine).

Obrazloženje takvog izračuna općenito je poznato i može se kratko opisati u nekoliko rečenica. Ako cijena nekog posla ili proizvoda u početnom trenutku (kraj 2002. godine) iznosi c_0 (nominalna cijena), ona će n godina kasnije iznositi:

Dutch example (the warehousing of SNF during the same period cost approximately 218 million euros), which shows that between these two projects there are no significant differences in expenditures.

Also, the estimated costs of the disposal of SNF were compared to a compilation by OECD/NEA [12] that demonstrates the large range of prices. The aforementioned cost estimates per unit measure of waste vary from 80 000 to 1 200 000 EUR/t of metallic uranium, and the lower unit prices are seen as a rule in countries that have larger quantities of fuel. The cost of the disposal of the SNF from the Program (916 000 EUR/t), pursuant to this rule, is near the upper limit of the aforementioned range.

Viewed as a whole, the cited comparisons contribute more to the impression of the realistic nature of the estimate of the total costs of the Program than facilitate an assessment of their unreliability due to potential developments in the social and political milieus.

3.2 The fiscal reliability of the estimated payments

In order to determine how many annuities must be paid to the national funds, a simple and transparent financial model has been chosen in the Program. It is easy to analyze its reliability as well as to correct the amounts of subsequent annuities in the event of significant changes in the interest and inflation rates.

The nominal costs of all the activities of the Program, determined according to the prices at the end of the year 2002, are primarily distributed according to a schedule of the years in which the work will be performed (assumed to be paid for at the end of each year). Subsequently, each nominal expenditure from the year in which it is planned is discounted as of the end of the year 2002. By adding together all the discounted amounts, the total discounted expenditures of the Program is obtained. It corresponds to the amount that, if it had been accruing interest since the year 2002 in some fund, would have been sufficient for the financing of all the future expenditures of the Program, the costs of which in the meantime will increase due to inflation (in comparison to the nominal prices from the year 2002).

The explanation of such a calculation is generally known and can be briefly explained in several sentences. If the price of a job or product at the initial moment (the end of the year 2002) is equal to c_0 (the nominal price), in n years it will equal:

$$c_n = c_0\, i^n, \tag{1}$$

gdje je i faktor inflacije.

Ako se u istom početnom trenutku novčana masa m_0 investira s kamatnim faktorom k, ona će nakon n godina narasti na:

where i is the inflation factor.

If at the same initial moment the monetary mass of m_0 is invested with an interest factor of k, it will after n years grow to:

$$m_n = m_0 \, k^n. \tag{2}$$

Da bi tako narasla novčana masa bila jednaka inflatiranoj cijeni:

In order for such an increased monetary mass to be equal to the inflated price:

$$m_0 \, k^n = c_0 \, i^n, \tag{3}$$

očito je trebalo imati početni iznos:

it is evident that it had to have the initial amount of:

$$m_0 = c_0 / d^n, \tag{4}$$

gdje je:

$d = k/i$ diskontni faktor.

Taj se početni iznos naziva cijenom posla ili proizvoda diskontiranom na 2002. godinu, te može biti znatno manji od nominalne cijene (ovisno o diskontnom faktoru), jer se pretpostavlja da se investirana novčana masa uvećava brže od inflacijskog rasta cijena.

U Programu korištena je godišnja stopa inflacije od 0,73 %, odnosno faktor inflacije 1,0073. Dobiveni su na temelju rasta cijena industrijskih proizvoda u Njemačkoj, koji je u razdoblju od 1995. do 2002. godine iznosio ukupno 5,23 %. To sedmogodišnje razdoblje odabrano je zato što su u Programu korišteni neki elementi izračuna troškova njemačke tvrtke NIS s cijenama iz 1995. godine, koje je prethodno trebalo revalorizirati na 2002. godinu. Za obračun kamata odabrana je dugoročna stopa na slovenske državne obveznice u eurima, koja je krajem 2003. godine iznosila 4,29 %, čemu odgovara kamatni faktor od 1,0429. Diskontna stopa dobivena iz navedenih faktora kamata i inflacije iznosi oko 3,53 % godišnje (preciznije, diskontni faktor na 6 decimala je 1,035342).

Nakon određivanja ukupnih diskontiranih troškova programa razgradnje, proveden je jednostavan izračun anuiteta. Odabran je uobičajeni konzervativni model jednakih anuiteta, kod

where:

$d = k/i$ is discount factor.

This initial amount is called the price of the job or product discounted as of the year 2002 and may be significantly less than the nominal price (depending upon the discount factor), because it is assumed that the invested monetary mass increases more rapidly than the inflationary increases in prices.

In the Program, the annual rate of inflation used is 0,73 %, i.e. an inflation factor of 1,0073, obtained on the basis of the price increases of industrial products in Germany, where during the period from 1995 to 2002 they amounted to a total of 5,23 %. This seven-year period was chosen because some elements of the calculation of the expenditures by the German firm of NIS from 1995 prices are used, which first had to be revalorized to the year 2002. For the calculation of the interest, the long-term rate on Slovenian state bonds in euros was chosen, which at the end of the year 2003 amounted to 4,29 %, corresponding to the interest factor of 1,0429. The discount rate obtained from the aforementioned factors of interest and inflation amounts to approximately 3,53 % annually (more precisely, the discount factor to 6 decimal places is 1,035342).

After the determination of the total discounted expenditures of the Program, a simple calculation of annuity was performed. A common conservative

kojih realna vrijednost uplata vremenom opada pa se lakše mogu uvesti korekcije naviše, ako budu potrebne. Pretpostavljeno je da će prva od 19 jednakih uplata u hipotetički zajednički fond biti izvršena krajem 2004. godine (u kojoj je dovršena izrada Programa), a posljednja na kraju 2022. godine (potkraj planiranog radnog vijeka NE Krško). Ako se ukupni trošak razgradnje diskontiran na kraj 2002. godine označi sa D, on treba biti jednak sumi svih anuiteta, u kojoj je vrijednost pojedinog anuiteta a uplaćenog n godina nakon 2002. umanjena faktorom k^{-n} (jer se kroz to vrijeme nije ukamaćivao).

To je parcijalna suma geometrijskog reda, iz koje se dobije:

model of equal annuities was chosen, in which the real value of the payments decline with time so that it is easier to make corrections upward, if necessary. It is assumed that the first of the 19 equal payments in the hypothetical joint fund would be completed by the end of the year 2004 (during which the preparation of the Program was completed), and the last in the year 2022 (at the end of the planned working lifetime of the Krško NPP). If the total decommissioning expenditures discounted at the end of the year 2002 are indicated by D, it should be equal to the sum of all the annuities, in which the value of an individual annuity a paid n years after 2002 is reduced by a factor of k^{-n} (because during this time it has not accrued interest).

This is the partial sum of the geometric series, from which the following is obtained:

$$a = D\,k(k-1)/(1-k^{-19}). \qquad (5)$$

Korišteni parametri i rezultati izračuna za usvojeni scenarij Programa rezimirani su u tablici 3. U preporukama Programa, međutim, diskontirani je trošak zaokružen naviše na 350 milijuna eura, čemu odgovara preporučeni anuitet od 28,5 milijuna eura za hipotetički zajednički fond (iznos anuiteta zaokružen je na jednu decimalu, preciznija vrijednost bila bi 28,48 milijuna eura).

The parameters used and the results of computations for the adopted Program scenario are summarized in Table 3. In the Program recommendations, however, the discounted expenditures are rounded upward to 350 million euros, accordingly corresponding to the recommended annuity of 28,5 million euros for the hypothetical joint fund. (The amount of the annuity is rounded to one decimal place, so that a more precise value would be 28,48 million euros.)

Tablica 3 – Pregled izračuna Programa razgradnje NE Krško
Table 3 – Review of the calculations of the decommissioning Program for the Krško NPP

Parametri / Parameters		Ukupni trošak Programa / Anuitet / Total Program Expenditures / Annuity (10^6 EUR)	
k faktor / factor	1,0429	Nominalni trošak (cijene iz 2002.) / Nominal expenditure (prices from the year 2002)	1 149,3
i faktor / factor	1,0073	Diskontirani trošak (na kraj 2002.) / Discounted expenditures (at the end of the year 2002)	338,5
d faktor / factor	1,0353	Anuiteti (krajem 2004. do 2022.) / Annuities (fromthe end of 2004 to 2022)	27,5

Za analizu pouzdanosti predloženog načina financiranja ovdje se koristi isti model diskontiranja kao u Programu, a u daljnjem će se tekstu razmatrati samo polovica hipotetičkog anuiteta za cijeli Program, tj. anuitet koji treba uplaćivati u hrvatski fond za razgradnju. Za izračun povećanja cijene hrvatske polovice električne energije iz NE Krško, kojim bi se ostvarile potrebne uplate, konzervativno će se uzeti 2004. godina zbog razmjerno niske proizvodnje. Tako dobivene polazne veličine za razmatranje hrvatskih troškova Programa navedene su u tablici 4.

For analysis of the reliability of the proposed manner of financing, the same discount model is used here as in the Program, and in the rest of the text only half of the hypothetical annuity for the entire Program will be considered, i.e. the annuity that is supposed to be paid into the Croatian fund for decommissioning. For the calculation of the increase in the price of the Croatian half of the electricity from the Krško NPP, by which the required payments will be covered, the year 2004 will be taken conservatively due to relatively low production. Thus, the initial amounts obtained for the discussion of the Croatian expenditures for the Program are presented in Table 4.

Tablica 4 – Hrvatski troškovi Programa razgradnje NE Krško
Table 4 – Croatian expenditures for the decommissioning of the Krško NPP

	Anuitet / Annuity (10^6 EUR)	Poskupljenje električne energije iz NE Krško / Surcharge on the electricity from the Krško NPP (EURc/kWh)
Proračunati / Calculated	13,75	0,53
Preporučeni / Recommended	14,25	0,55

Ključni problem za analizu fiskalne pouzdanosti izračuna anuiteta je odabir diskontne stope. Ona je približno jednaka razlici između očekivane kamatne i inflacijske stope, te opisuje očekivanja da će fond za razgradnju dobro poslovati. Diskontna stopa od 3,53 %, dobivena u Programu na temelju odabranih stvarnih podataka o inflaciji i kamatama, vrlo je blizu iznosa od 3,5 % koji se često koristi u sličnim dugoročnim projektima. Za raspravu fiskalne pouzdanosti preporuka Programa, ovdje je najprije provedeno variranje godišnje diskontne stope u uobičajenom rasponu od 1 % do 5 %, koristeći model jednakih anuiteta kao u Programu (za iste iznose i raspored nominalnih troškova), a rezultati su prikazani u tablici 5 i na slici 1.

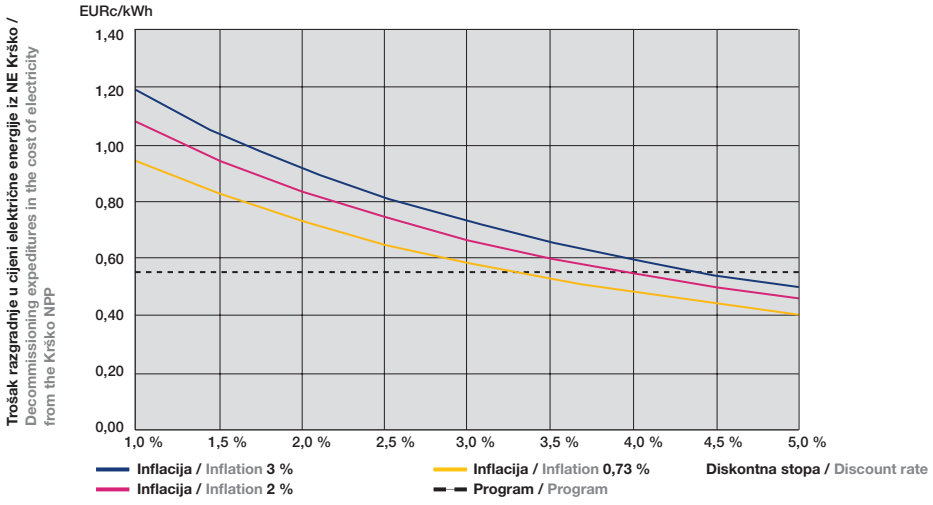
The key problem in the analysis of the fiscal reliability of the calculation of the annuity is the selection of the discount rate. It is nearly equal to the difference between the anticipated interest and inflation rate, and assumes that the decommissioning fund will operate successfully. The discount rate of 3,53 %, obtained in the Program on the basis of selected actual data on inflation and interest, is very close to the amount of 3,5 %, which is frequently used in similar long-term projects. For the discussion of the fiscal reliability of the Program recommendations, varying annual discount rates were first used within the customary range of from 1 % to 5 %, with the application of the model of equal annuities as in the Program (for the same amounts and distribution of nominal expenditures), and the results are presented in Table 5 and Figure 1.

Tablica 5 – Ovisnost anuiteta o diskontnoj stopi i o stopi inflacije
Table 5 – The dependence of the annuity on the discount rate and on the inflation rate

Diskontna stopa / Discount rate (%)	Anuitet / Annuity (10^6 EUR)		
	uz inflaciju / with inflation of 0,73 %	uz inflaciju / with inflation of 2 %	uz inflaciju / with inflation of 3 %
1,0	24,65	28,04	30,91
1,5	21,65	24,59	27,06
2,0	19,17	21,73	23,88
2,5	17,09	19,34	21,23
3,0	15,35	17,34	19,00
3,5	13,87	15,64	17,11
4,0	12,60	14,18	15,50
4,5	11,51	12,93	14,12
5,0	10,56	11,85	12,92

Dok diskontirani trošak ovisi samo o odnosu kamata i inflacije (tj. o diskontnoj stopi), anuiteti ovise i o apsolutnom iznosu kamata ili inflacije. Šesti redak u tablici 5 prikazuje anuitete pri diskontnoj stopi 3,5 % (približno jednakoj stopi u Programu); za stopu inflacije Programa od 0,73 % anuitet iznosi 13,87 milijuna eura (približno kao proračunati hrvatski anuitet u Programu). No, pri stopi inflacije od 3 %, anuitet bi bio znatno veći i iznosio bi 17,11 milijuna eura. To je razumljiva posljedica modela financiranja nominalno jednakim anuitetima, kojima realna vrijednost tijekom 19 godina opada, i to utoliko više što je veća inflacija (pa im zato početna nominalna vrijednost mora biti veća).

While the discounted expenditure depends only upon the ratio between interest and inflation (i.e. on the discount rate), annuities also depend on the absolute amount of interest or inflation. The sixth row in Table 5 presents annuities at a discount rate of 3,5 % (approximately equal to the rate in the Program); for the inflation rate of 0,73 % in the Program, the annuity amounts to 13,87 million euros (approximately equal to the calculated Croatian annuity in the Program). However, at an inflation rate of 3 %, the annuity would be significantly larger and amount to 17,11 million euros. This is an understandable consequence of the model for the financing of nominally equal annuities, the real values of which decline over a period of 19 years. The higher the rate of inflation, the greater decline in the real values of the annuities (and therefore the initial nominal value must be higher).



Slika 1
Ovisnost procjene troška o diskontnoj stopi i o stopi inflacije
Figure 1
Dependence of the costs estimate on the discount rate and on the inflation rate

Međutim, za dugoročne se projekte može odabrati i model financiranja anuitetima jednake realne vrijednosti, kojima nominalni iznosi tijekom vremena rastu sukladno pretpostavljenoj inflaciji (ovdje će se za njih koristiti i kraći naziv - rastući anuiteti). U tablici 6 i na slici 2 prikazan je taj vremenski rast, odnosno rast nominalnog opterećenja cijene struje iz NE Krško u tome modelu, za diskontnu stopu od 3,5 %.

However, for long-term projects it is also possible to choose a model for financing annuities of equal real value, for which the nominal amounts over time increase pursuant to the assumed inflation (henceforth: escalating annuities). In Table 6 and Figure 2, this temporal growth is presented, i.e. the growth of the nominal surcharge on the price of electricity from the Krško NPP in this model, at a discount rate of 3,5 %.

Rastući anuiteti jednake realne vrijednosti dobivaju se množenjem prethodnog anuiteta s faktorom inflacije i. Ako se s a označi prvi anuitet (za 2004. godinu), 2005. godine treba uplatiti ai, 2006. godine ai^2, itd. Jednostavnim se razmatranjem za iznos prvog anuiteta dobije izraz sličan relaciji (5), u kojemu se umjesto kamatnog faktora pojavljuje diskontni faktor d:

Escalating annuities of equal real value are obtained by multiplying the previous annuity by the inflation factor i. If a signifies the first annuity (for the year 2004), for the year 2005 it is necessary to pay ai, for 2006 ai^2 etc. For the calculation of the amount of the first annuity, an equation similar to expression (5) is obtained, in which the interest factor is replaced by the discount factor d:

$$a = Di^2\, d(d-1) / (1 - d^{19}). \qquad (6)$$

Kako se vidi iz tablice 6 i slike 2, u modelu rastućih anuiteta jednake realne vrijednosti, pri zadanoj diskontnoj stopi, početna nominalna izdvajanja približno su jednaka za sve stope inflacije (bila bi točno jednaka da se prva godina uplaćivanja podudara s godinom na koju je provedeno diskontiranje). Ako se anuiteti financiraju poskupljenjem električne energije iz NE Krško, sva izdvajanja (prikazana rastućim krivuljama na slici 2) predstavljaju kroz cijelo to vrijeme isti postotak tržišne cijene električne energije, uz pretpostavku da i ona raste prema istom faktoru inflacije i (iste krivulje prikazivale bi i rast cijene električne energije, ako se iznosi na ordinati pomnože s odgovarajućim faktorom).

As seen from Table 6 and Figure 2, in the model of escalating annuities of equal real value, at the given discount rate, the initial nominal payments are nearly equal for all the inflation rates (they would be precisely equal if during the first year the payment coincided with the year during which the discount was performed). If the annuities are financed by increasing the price of electricity from the Krško NPP, all the allocations throughout that period (shown by the rising curves in Figure 2) represent the same percentage of the market price of electricity, assuming that it is increasing according to the same factor of inflation i (the same curves also present the increases in the price of electricity, if the amounts on the ordinates are multiplied by the corresponding factor).

Tablica 6 – Anuiteti jednake vrijednosti pri diskontnoj stopi 3,5 %
Table 6 – Annuities of equal value at a discount rate of 3,5 %

Godina / Year	Inflacija / Inflation 0,73 %	Inflacija / Inflation 2 %	Inflacija / Inflation 3 %
	Anuitet / Annuity (10^6 EUR)	Anuitet / Annuity (10^6 EUR)	Anuitet / Annuity (10^6 EUR)
2004.	13,10	13,43	13,69
2007.	13,38	14,25	14,96
2010.	13,68	15,12	16,35
2013.	13,98	16,05	17,87
2016.	14,29	17,03	19,52
2019.	14,61	18,07	21,33
2022.	14,93	19,18	23,31

Prethodna razmatranja dokazuju da proračunate uplate dramatično ovise o izboru modela financiranja i njegovih parametara, za iste nominalne troškove Programa i isti period uplaćivanja. Uz to, potrebno je razlikovati raspon nominalnih iznosa uplata od raspona njihovih realnih vrijednosti.

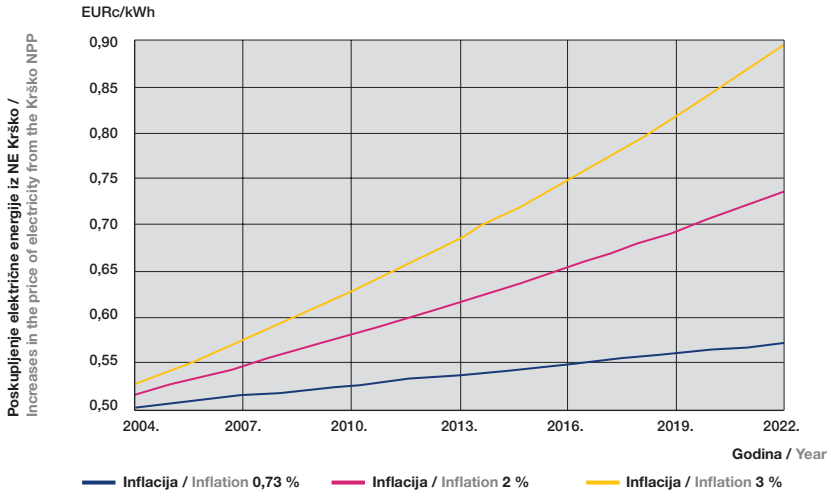
Ako se koristi model jednakih anuiteta, tj. jednakih nominalnih iznosa uplata u cijelom periodu (koji je u Programu odabran da bi se očuvala konzervativnost pristupa pri maloj pretpostavljenoj stopi inflacije), dobije se vrlo veliki raspon iznosa potrebnih uplata za promatrani izbor financijskih parametara (tablica 7). Gornji iznos (pri diskontnoj stopi od 1 % i stopi inflacije od 3 %) je čak 2,17 puta (ili za 117 %) veći od preporuka Programa,

The previous discussion demonstrates that the calculation of payments dramatically depends upon the choice of the financing model and its parameters for the same nominal expenditures of the Program and the same period of payment. Moreover, it is necessary to differentiate the range of the nominal amounts of payment from the range of their real values.

If a model of equal annuities is used, i.e. equal nominal payments during the entire period, which was chosen in the Program in order to preserve the conservative approach, with a low assumed rate of inflation, a large range of amounts is obtained for the necessary payments for the considered selection of financial parameters (Table 7). The highest amount (at a discount rate of 1 % and an inflation rate of

prema kojima je uredbom Hrvatske vlade određena visina HEP-ovih uplata.

3 %) is 2.17 times (or 117 %) greater than the Program recommendations, pursuant to which the enactment of the Croatian Government determined the amount of HEP's payments.



Slika 2
Izdvajanja jednake vrijednosti pri diskontnoj stopi 3,5 %
Figure 2
Allocations of equal value at a discount rate of 3,5 %

Međutim, pri znatnim stopama inflacije nije primjereno uspoređivati nominalne visine uplata u modelu jednakih anuiteta (jer im realna vrijednost brzo opada, i to ovisno o inflaciji), niti je vjerojatno da bi se taj model doista koristio. Kod znatne inflacije, relevantnija je usporedba uplata za različite diskontne stope u modelu rastućih anuiteta jer im se realna vrijednost ne mijenja s vremenom. Za prikaz raspona takvih uplata (posljednji red tablice 7) odabran je njihov početni iznos, tj. 2004. godina. I u ovom je slučaju gornji iznos (pri diskontnoj stopi od 1 % i stopi inflacije od 3 %) znatno veći (za 70 %) od preporuka Programa. U idućim godinama omjer bi postajao još nepovoljniji (veći), dakako ne zbog rasta relativnog opterećenja cijene električne energije, nego zbog pada realne vrijednosti preporučenih jednakih anuiteta iz sadašnjeg Programa.

However, when there is significant inflation, it is not appropriate to compare the nominal amounts of payments in a model of equal annuities (because their real value rapidly declines due to inflation), and it is also not likely that such a model would actually be used. In the case of significant inflation, it is relevant to compare the payments according to the various discount rates in a model of escalating annuities because their real value does not change with time. For a presentation of the range of such payments (the last row of Table 7), the initial amount has been selected, i.e. the year 2004. In this case, the upper amount (at a discount rate of 1 % and an inflation rate of 3 %), is significantly higher (by 70 %) than the Program recommendations. In subsequent years, the ratio would become even less favorable (higher), not due to the increase of the relative surcharge on the price of electricity but due to the decline in the real values of the recommended equal annuities from the current Program.

Tablica 7 – Ovisnost uplata za 2004. godinu o modelima i parametrima
Table 7 – Dependence of the payments for 2004 on the model and parameters

Model / Model	Diskontna stopa 5 % uz inflaciju 0,73 % / Discount 5 % with inflation at 0,73 %		Diskontna stopa 1 % uz inflaciju 3 % / Discount 1 % with inflation at 3 %	
	(10^6 EUR)	(EURc/kWh)	(10^6 EUR)	(EURc/kWh)
Jednaki anuiteti / Equal annuities	10,56	0,41	30,91	1,19
Rastući anuiteti / Escalating annuities	10,01	0,38	24,21	0,93

Usto, već spomenuta pogodnost modela rastućih anuiteta, te da sama inflacija nema znatnog utjecaja na visinu početnih uplata, dopušta da se u ovoj analizi ne razmatraju eksplicitno stope inflacije veće od 3 %. To, međutim, nameće ograničenje da se ne provode nepažljive usporedbe s nominalno jednakim anuitetima, odnosno, da se provede korektno obrazloženje odnosa vrijednosti u kasnijim ratama.

No, bez obzira na model financiranja, za odabrani raspon parametara je očigledno da je fiskalna pouzdanost procjene troškova razgradnje daleko slabija od tehničke pouzdanosti, te se ne može reducirati ispod reda veličine otprilike oko 100 % u ovako ranoj fazi financiranja projekta.

Štoviše, moglo bi se tvrditi da ni tako visoka ocjena nepouzdanosti ne obuhvaća puni raspon fiskalnih rizika. Iako je to u načelu točno, jer nije moguće isključiti rizike od nepredvidljivog potpunog financijskog sloma, nijedan model financiranja projekata pomoću fondova koji komercijalno posluju ne može smisleno obuhvatiti takve rizike, već se protiv njih uvode vanjski instrumenti osiguranja (kao što je npr. krajnja odgovornost države za projekte razgradnje nuklearnih postrojenja). Stoga se u ovakvim analizama pretpostavlja kontinuirano pozitivno poslovanje fondova, a rasprava pouzdanosti procjene ograničava se na prikladnost odabira financijskog modela i njegovih parametara.

U provedenom razmatranju korišteni su uobičajeni modeli financiranja i tipični raspon diskontnih stopa koje se primjenjuju u sličnim projektima. Mogućnost razmatranja diskontne stope veće od 5 % nema praktičnog značenja: ona je dugoročno malo vjerojatna i nepotrebno bi sugerirala opciju preniskih anuiteta. No, ključno je pitanje treba li razmatrati diskontne stope manje od 1 %, pri kojima je oplođivanje realne vrijednosti uplata zanemarivo malo, pa bi njihov iznos trebalo dodatno uvećati (tj. znatno više od 100 % u odnosu na preporuke Programa).

To je, dakako, moguće, te ima i primjera planiranja razgradnje uz nultu diskontnu stopu, no uz takvu je pretpostavku besmislen model financiranja pomoću fondova koji komercijalno posluju. Ako se od fondova ne očekuje nikakva zarada, logičnije bi bilo uplaćivati sredstva u državni proračun, i daljnju brigu o pokrivanju troškova razgradnje od početka prepustiti državi. No, kako je za Program predviđeno financiranje iz dvaju nacionalnih fondova (od kojih jedan već godinama uspješno komercijalno posluje), za ovu se analizu smatra razumnim pretpostaviti da je dugoročno ostvariva kamatna stopa toliko veća od inflacije da ne

In addition, due to the previously mentioned suitability of the model of escalating annuities and the fact that inflation does not have a significant impact on the amount of the initial payments, in this analysis explicit inflation rates of greater than 3 % are not discussed. This, however, requires the avoidance of making casual comparisons to nominally equal annuities, i.e. it is necessary to provide a correct explanation of the relations among the values in the later installments.

However, regardless of the financing model, for the selected range of parameters it is evident that the fiscal reliability of the estimated decommissioning costs is far less than the technical reliability, and that it cannot be reduced below an order of magnitude of approximately 100 % in this early phase of the financing of the project.

Moreover, it could be stated that even such a high estimate of unreliability does not cover the full range of fiscal risk, and therefore it is precise in principle, because it is not possible to exclude the risk from an unforeseen total financial collapse. No model of financing the project using funds that operate commercially can rationally cover such risks, but external instruments of insurance have been introduced to combat them (such as, for example, the ultimate responsibility of the state for the projects of the decommissioning of nuclear power plants). Therefore, continuous positive operations of the funds are assumed in such analyses, and discussion of the reliability of estimates is limited to the suitable selection of a financial model and its parameters.

In performing the analysis, customary models of financing and the typical range of discount rates that are applied in similar projects have been used. The possibility of analyzing discount rates greater than 5 % does not have practical significance; such rates are unlikely over a long period and it would not be necessary to suggest the option of annuities that are too low. However, a key question is whether it is necessary to analyze discount rates lower than 1 %, at which the accruement of interest on the real value of the payments is negligible, so that the amount should be further increased (i.e. significantly higher than 100 % in relation to the Program recommendations).

This is, indeed, possible and there is the example of planned decommissioning with a zero discount rate, but besides this there is also the assumption of an absurd model of financing using funds that operate commercially. If no earnings were anticipated from the funds, it would be logical to pay the funds into the state budget and the further coverage of the costs of decommissioning would be left to the state from the beginning. However, since financing is anticipated for the Program from two national funds (of which one

treba razmatrati diskontne stope manje od 1 %. Time se granica fiskalne nepouzdanosti zadržava na oko 100 % u odnosu na uplate preporučene Programom.

Navedena ocjena fiskalne pouzdanosti preporučenih uplata ima smisla samo u ukupnom kontekstu prethodnih razmatranja. Ona se temelji na financijskom modelu Programa, pretpostavlja njegovo dosljedno provođenje i odnosi se na ukupno njegovo financiranje. Stoga treba posebno naglasiti sljedeće:

– Uredba Hrvatske vlade, prema kojoj HEP uplaćuje sredstva u državni proračun (umjesto da je osnovan fond sličan slovenskom), ne uklapa se u financijski model Programa. Dodatno odstupanje od toga modela uvedeno je rastezanjem zaostalih uplata na idućih 5 godina, ali će negativni učinak kašnjenja biti djelomično kompenziran kvartalnim uplatama, ako se fond osnuje uskoro (Program je konzervativno pretpostavio uplate krajem godine).

  Procjenu potrebne korekcije zbog odstupanja sadržaja Uredbe od financijskog modela Programa najjednostavnije je prikazati kao manjak u budućem fondu na kraju 2011. godine (u kojoj bi trebalo dovršiti uplaćivanje zaostalih rata). Tablica 8 prikazuje kako taj manjak ovisi o datumu osnivanja fonda, uz pretpostavku da se do tada sredstva uplaćena u državni proračun samo evidentiraju, dok bi se u fondu oplođivala prema kamati iz Programa.

has already been successfully operating commercially for years), for this analysis it is considered responsible to assume that the long-term feasible interest rates are sufficiently higher than inflation and that it is not necessary to analyze discount rates lower than 1 %. Therefore, the limits of the fiscal unreliability are maintained at approximately 100 % in relation to the payments recommended by the Program.

The aforementioned assessment of the fiscal reliability of the recommended payments only makes sense within the overall context of the previous analysis. It is based upon the financial model of the Program, assumes its consistent implementation and relates to its overall financing. Therefore, it is necessary to emphasize the following:

– The enactment of the Croatian Government, according to which HEP contributes to the state budget (instead of establishing a fund similar to the Slovenian one), does not fit into the financial model of the Program. Additional deviation from this model has been introduced by extending the remaining payments over the subsequent five years. The negative impact of the delay will be partially compensated for by quarterly payments, providing that the fund is established soon (the Program has conservatively assumed payment by the end of the year).

  Due to deviation of the content of the enactment from the financial model of the Program, the assessment of the necessary corrections is presented most simply as a deficit in the future fund at the end of the year 2011 (during which the payment of the remaining installments should be completed). Table 8 presents how this deficit depends on the date of the establishment of the fund, with the assumption that until then the contributions paid to the state budget are only recorded, while in the fund they would be accruing income according to the interest rate from the Program.

Tablica 8 – Manjak ovisno o datumu osnivanja fonda
Table 8 – The deficit, depending upon the date of the establishment of the Fund

Osnivanje fonda / Establishment of the Fund	Način uplate / Manner of payment	Stanje na kraju 2011. / Status at the end of 2011 (10^6 EUR)	Manjak / Deficit (10^6 EUR)
Kraj 2004. / End of 2004	Krajem godine / Year end	132,67	0,00
30. lipnja 2006. / June 30, 2006	Kvartalno, prema vladinoj Uredbi / Quartely, according to the Goverment Enactment	129,27	3,40
Kraj 2007. / End of 2007		127,66	5,01
Kraj 2009. / Enf of 2009		122,34	10,33
Kraj 2011. / End of 2011		114,00	18,67

Ako bi se fond osnovao u vrijeme prvih HEP-ovih uplata (kraj lipnja 2006), sredstva akumulirana do kraja 2011. godine bila bi za 3,4 milijuna eura manja nego da se postupalo prema preporuci Programa. Malo odgađanje osnivanja fonda neće dramatično uvećati taj manjak, ali bi se za nekoliko godina uvećao nekoliko puta. A u ekstremnom slučaju (nije prikazan u tablici 8) da Hrvatska uopće ne osnuje fond za razgradnju NE Krško koji bi oplođivao uplaćena sredstva, već istu svotu hoće prikupiti jednostavnim pribrajanjem 19 anuiteta na pasivnom računu, iznos svakog anuiteta trebalo bi uvećati s 14,25 na 42,51 milijuna eura.

– Odstupanja od planirane dinamike korištenja sredstava mogu značajno promijeniti izračun anuiteta. Primjerice, ako bi se sadašnji slovenski planovi o otvaranju odlagališta NSRAO u 2013. godini (umjesto u 2018.) prihvatili kao izmjena u Programu, diskontirani troškovi odlaganja NSRAO porasli bi s 93,9 na 111,5 milijuna eura, tj. za 18,8 %. U ukupnim troškovima Programa to bi povećanje iznosilo 5,2 %. Ako bi se jednako rasporedilo na obadva fonda, preporučene hrvatske anuitete (svih 19) trebalo bi povećati s 14,25 na 14,99 milijuna eura, tj. za 740 000 eura svaki.
– Sumarna ocjena o granici nepouzdanosti otprilike oko 100 % je kompromis kojim se izbjegava daljnja rasprava o distinkcijama između modela jednakih i rastućih anuiteta (općenito poznata u modeliranju komercijalnog financiranja dugoročnih projekata), koja bi se mogla sustavno provesti na temelju prethodnih razmatranja. Ona bi pokazala kako bi nominalne iznose nekih uplata na nepovoljnoj granici promatranog raspona parametara trebalo uvećati i znatno više od 100 %, ali bi pritom njihova realna vrijednost u odnosu na sadašnje preporučene uplate ostala ispod 100 %.
– Glavna svrha ocjene nepouzdanosti je da pokaže kolika bi povećanja uplata mogla biti potrebna u nepovoljnim okolnostima. Navedena ocjena o granici od 100 % odnosi se, međutim, na korekciju ukupnih uplata u predloženom modelu hrvatskih izdvajanja za Program. Budući da još nije počelo ni planiranje iduće revizije Programa, malo je vjerojatno da bi eventualne korekcije (čak i kad bi potreba za njima bila već sada očigledna) mogle započeti prije 2010. godine. Stoga će se eventualno povećanje uplata (u prethodnoj analizi raspoređeno na svih 19 godišnjih rata) trebati ostvariti kroz 12–13 preostalih rata, što znači da bi se u linearnoj preraspodjeli povećanje rata od 100 % pretvorilo u povećanje preostalih rata

If the fund had been established at the time of HEP's first payments (at the end of June 2006), the monetary resources accumulated up to the end of the year 2011 would be 3,4 million euro less than if the recommendations of the Program had been followed. A slight delay in the establishment of the fund would not dramatically increase this deficit but it would increase several times in several years. In the extreme situation (not shown in Table 8) that Croatia does not establish a fund at all for the decommissioning of the Krško NPP that would accrue income from interest, but instead simply wants to collect 19 annuities in a passive account, the amount of each annuity should be increased from 14,25 million euros to 42,51 million euros.

– Deviations from the planned dynamics for the use of monetary resources could significantly change the calculation of the annuities. For example, if the current Slovenian plans for the opening of a repository for LILW in the year 2013 (instead of 2018) are accepted as an amendment to the Program, the discounted expenditures for the disposal of LILW would increase from 93,9 to 111,5 million euros, i.e. by 18,8 %. In the total expenditures of the Program, this increase would amount to 5,2 %. If this were to be equally distributed in both funds, the recommended Croatian annuities (all 19) would have to be increased from 14,25 million euros to 14,99 million euros, i.e. by 740 000 euros each.
– The summarized evaluation of the unreliability limits of approximately 100 % is a compromise to avoid further discussion about the distinctions between the models of equal and escalating annuities (generally known in the modeling of the commercial of long-term projects), which could be systematically performed on the basis of the previous analyses. It would demonstrate that the nominal amounts of some payments at the unfavorable limit of the parameter range being considered should be increased by significantly more than 100 %, but their real value in relation to the currently recommended payments would remain below 100 %.
– The main purpose of the evaluation of unreliability is to demonstrate how much of an increased payment would be necessary under unfavorable circumstances. The stated evaluation of the limit of 100 % refers, however, to the correction of the total payments in the proposed model for Croatian allocations for the Program. Since the next audit of the Program has not been begun planned, it is unlikely that eventual corrections (even if the need for them were already evident) could be instituted before the year 2010. Therefore, an eventual payment increase (in the previous analysis distributed

od 150 %. Međutim, preraspodjela mora biti nepovoljnija od linearne, jer se ranije uplate nadomještaju kasnijima; a ako se još uzme u obzir kašnjenje prvih hrvatskih rata, sumarna ocjena nepouzdanosti za hrvatske uplate od 2010. godine nadalje bliža je granici od 200 % nego 100 % od iznosa sadašnjih rata.

Ne može se decidirano tvrditi da je potreba za značajnim korekcijama budućih uplata već sada očigledna, ali su sve čvršće indicije da će se mijenjati iznosi parametara korištenih u izračunu Programa. Prema podacima Statističkog ureda Europske zajednice [13], prosječne dugoročne kamate na državne obveznice u euro-zoni značajno su se smanjile, od 4,14 % iz 2003. godine na 3,42 % u 2005. godini (u Sloveniji na 3,81 %). Istodobno, rast cijena industrijskih proizvoda (bez energetike i graditeljstva), koji je 2000. – 2004. godine bio manji od 1 % godišnje, u posljednje dvije godine kreće se po godišnjoj stopi oko i iznad 2 %.

Ako bi se zadržao sadašnji odnos kamata i inflacije, a izbor parametra Programa orijentirao prema prosječnim pokazateljima euro-zone, trebalo bi diskontnu stopu spustiti na oko 1,5 %, što bi godišnju uplatu u modelu 19 jednakih anuiteta podiglo na skoro 25 milijuna eura. Ipak, još je prerano za takva predviđanja, jer ima naznaka da se i na kamatnim stopama počinje osjećati utjecaj inflacije uzrokovane poskupljenjem nafte. Već i manji oporavak diskontne stope mogao bi njezinu prosječnu vrijednost u periodu između dvije revizije Programa zadržati iznad 2 %, što znači da bi dostajalo znatno manje povećanje anuiteta. Ako se usto uzme u obzir da cijene energenata rastu znatno brže nego industrijskih proizvoda, relativna vrijednost daljnjih potrebnih izdvajanja za razgradnju NE Krško (u odnosu na cijenu električne energije) možda će se tek neznatno povećavati. No, ako ne dođe do dramatičnog pada inflacije, nominalni iznos preostalih anuiteta svakako će osjetno porasti.

among all 19 annual installments) should be achieved through the 12–13 remaining installments, which means that in the linear distribution the increased installment of 100 % would be transformed into a 150 % increase in the remaining installments. However, reallocation should be less favorable than linear, because previous payments replace later ones; and if the delay in the first Croatian installments is taken into account, the summary evaluation of unreliability for Croatian payments from 2010 onward is nearer the limit of 200 % than 100 % of the amount of the current installments.

It cannot be stated decisively that the need for significant corrections of the future payments is already evident but there are increasingly solid indications that the ratios of the parameters used in the calculation of the Program will change. According to statistical data of the European Community [13], the average long-term interest on state bonds in the euro zone has significantly declined from 4,14 % in the year 2003 to 3,42 % in the year 2005 (in Slovenia to 3,81 %). At the same time, the increase in the prices of industrial products (excluding energy and construction), which in 2000 – 2004 was less than 1 % per year, has ranged during the past two years at an annual rate of around and over 2 %.

If the current ratio between interest and inflation continues, and the choice of the parameters of the Program will be oriented to the average indices of the euro zone, the discount rate should be reduced to approximately 1,5 %, which would raise the annual payments in the model of 19 equal annuities to nearly 25 million euros. Nonetheless, it is still too early for such a forecast because there are indications that the impact of inflation due to rising oil prices is beginning to be felt on interest rates. A slight recovery in the discount rate could keep its average value in the period between the two audits of the Program at above 2 %, which means that a significantly lower increase in the annuities would be sufficient. If it is also taken into account that the prices of energy sources are rising significantly more rapidly than those of industrial products, the relative value of the further required allocations for the decommissioning of the Krško NPP (in relation to the price of electricity) could increase insignificantly. However, if no dramatic decline in inflation occurs, the nominal amount of the remaining annuities will certainly rise perceptibly.

4 HIPOTETIČKI SCENARIJI PRODULJENOG FINANCIRANJA RAZGRADNJE

Za ocjenu relativne opterećenosti cijene električne energije Programom u širem kontekstu, osobito prema drugim projektima razgradnje nuklearnih elektrana, prikladno je analizirati i dva hipotetička scenarija produljenog financiranja razgradnje.

4.1 Što bi bilo da je hrvatski fond ustanovljen 1994. godine

Ovaj je scenarij posve hipotetički, ali je prikladan za usporedbu sa slovenskim izdvajanjima za Program, budući da je tada osnovan njihov fond. U tablici 9 uspoređuju se aktualna hrvatska izdvajanja za Program s onima koja bi se dobila u istom financijskom modelu da je uplaćivanje u hrvatski fond bilo planirano od 1994. godine (provedena su ekvivalentna mala zaokruživanja naviše kojima se iz proračunatog anuiteta dobio aktualni iznos od 14,25 milijuna).

4 HYPOTHETICAL SCENARIOS FOR THE PROLONGED FINANCING OF DECOMMISSIONING

For the assessment of the relative surcharge on electricity prices by the Program in the broad context, particularly according to other projects for the decommissioning of nuclear power plants, it is also appropriate to analyze two hypothetical scenarios for the prolonged financing of decommissioning.

4.1 What would have happened if the Croatian Fund had been established in the year 1994?

This scenario is entirely hypothetical but it is suitable for comparison to the Slovenian allocations for the Program, since their fund was established then. In Table 9, the actual Croatian allocations for the Program are compared to those that would have been obtained in the same financial model if payments into the Croatian fund had been planned as of the year 1994 (there has been slight rounding upwards of the figures, according to which the calculated annuity was 14,25 million).

Tablica 9 – Usporedba godišnjih izdvajanja za periode od 19 i 29 godina
Table 9 – Comparison of annual allocations for the period of 19 and 29 years

Godina prve uplate / Year of the first payment	Broj anuiteta / Number of annuities	Anuitet / Annuity (10^6 EUR)	Poskupljenje / Increase in cost (EURc/kWh)
2004.	19	14,25	0,55
1994.	29	7,31	0,28

Da je hrvatski fond za razgradnju počeo s radom 1994. godine, godišnje bi uplate u istom modelu financiranja bile upola manje. Sadašnje stanje bilo bi gotovo identično slovenskom, mada je njihova akumulacija u proteklom periodu ostvarena nižim uplatama i većim prihodima fonda.

4.2 Hipotetički scenarij produljenja radnog vijeka NE Krško za 20 godina

Produljenje radnog vijeka NE Krško opcija je koja se u Hrvatskoj neslužbeno razmatra već neko vrijeme (a u Sloveniji se počela pojavljivati i u službenim dokumentima). Iako je to za sada još posve hipotetički scenarij, s tehničkog i regulatornog stajališta moguće je radni vijek elektrane produljiti za 20 godina, tj. povećati ga za 50 % u odnosu na sadašnji plan. U pogledu nominalnih troškova Programa razgradnje,

If the Croatian fund for decommissioning had started operating in the year 1994, the payments in the same model of financing would be half as much. The present situation would be nearly equal to that of Slovenia, although their accumulation during the past period was achieved with lower payments and greater incomes from the fund.

4.2 Hypothetical scenario of the prolongation of the working lifetime of the Krško NPP by 20 years

Prolongation of the working lifetime of the Krško NPP is an option that has been discussed unofficially in Croatia for some time and in Slovenia has begun to appear in official documents. Although for now it is an entirely hypothetical scenario, from the technical and regulatory standpoints it is possible to prolong the working lifetime by 20 years, i.e. to increase it by 50 % in relation to the current plan.

posljedice 50 % dužeg rada NE Krško mogu se grubo procijeniti pomoću sljedećih pretpostavki:

- Količina NSRAO mogla bi se uvećati i za više od 50 %, zbog starenja postrojenja i eventualnih zamjena dijelova. Stoga će se pretpostaviti 100 % povećanje NSRAO, što zahtijeva odlagalište dvostrukog kapaciteta. Ako bi se planirala modularna gradnja odlagališta, najjeftinije bi bilo dodavati module prema potrebi. Umjesto toga, konzervativno će se pretpostaviti izgradnja još jednog nezavisnog odlagališta, koje je identično do sada planiranome, ali koje će biti pušteno u pogon 20 godina nakon prvog odlagališta, upravo kada je planiran početak zatvaranja prvoga. To će udvostručiti nominalne troškove za NSRAO planirane u sadašnjem Programu, ali će znatno manje utjecati na njihovu diskontiranu cijenu.
- Količina ING će se uvećati za oko 50 %, no izgradnja za toliko većeg odlagališta ne povećava sve nominalne troškove za 50 %. Usto, u njemu će znatno porasti udio dobro ohlađenih elemenata ako se početak odlaganja odgodi u skladu s produženim radom NE Krško. S druge strane, unaprijed je jasno da bi moguća odgoda ukupne izgradnje odlagališta za 20 godina jako obezvrijedila svako povećanje nominalnih troškova prilikom izračuna diskontirane cijene. K tome, takvo produženje projekta dodatno povećava nepouzdanost procjene, što je osobito nepoželjno za trošak odlaganja ING, koji je najveći nominalni trošak u Programu. Zato će se pretpostaviti da se sve aktivnosti vezane uz odlagalište ING odvijaju samo 10 godina kasnije nego u sadašnjem Programu, i to uz 50 % povećane nominalne troškove. Takva je pretpostavka opravdana i zato što ni projektno-tehnički argumenti o hlađenju gorivih elemenata neće više poticati na dulje odgađanje. Opcija produljenja radnog vijeka NE Krško pojačava razloge za suho skladištenje ING predviđeno Programom. Najjednostavnije je konzervativno pretpostaviti da će skladište planiranog kapaciteta početi s radom prema sadašnjem rasporedu u Programu (iako bi tehnološki moglo početi i kasnije, i/ili sa znatno manjim kapacitetom), a da će samo dodatnih 50 % prostora i spremnika biti uključeno 20 godina kasnije, te proporcionalno povećati nominalne troškove.
- Kod razgradnje elektrane, koja se u cijelosti odgađa za 20 godina, pretpostavit će se povećanje nominalnih troškova za 50 %, više zbog nepouzdanosti modela produženog financiranja nego zbog minornog doprinosa eventualnih tehničkih rekonstrukcija.

Regarding the nominal expenditures of the Program, the consequences of a 50 % increase in the working lifetime of the Krško NPP may be roughly assessed with the help of the following assumptions:

- The quantity of the LILW could be increased by more than 50 % due to the aging of the plant and the eventual replacements of parts. Therefore, a 100 % increase in the LILW will be assumed, which requires a repository with twice the capacity. If a modular construction of the repository is planned, it would be the least expensive to add modules as needed. Instead of this, the construction of one more independent repository will be conservatively assumed, which would be identical to the one planned but would be placed into operation 20 years after the first repository when the closing of the first is planned. This will double the nominal expenditures for LILW planning in the current Program but will have significantly less impact on its discounted price.
- The quantity of the SNF will increase by approximately 50 % but the construction of such a large repository does not increase all the nominal expenditures by 50 %. Moreover, the share of good refrigerated elements will significantly rise if the beginning of disposal is postponed by the prolonged operation of the Krško NPP. From the other side, it is clear that the possible postponement of the construction of the repositories by 20 years would greatly devaluate all the increased nominal costs during the calculation of the discount price. Furthermore, such a prolongation of the project additionally increases the unreliability of the estimate, which is particularly undesirable regarding the cost of the disposal of SNF, which is the highest nominal expenditure in the Program. Therefore, it will be assumed that all the activities in connection with the repository for the SNF should be performed only 10 years later than in the current Program, and this with a 50 % increase in the nominal expenditures. Such an assumption is justified and therefore even the project-technical arguments on the cooling of the fuel elements will no longer affect the length of postponement. The option of the prolongation of the working lifetime of the Krško NPP strengthens the reasons for the dry warehousing of SNF anticipated by the Program. It is simplest to assume conservatively that the warehouse of the planned capacity will commence operations according to the current Program schedule (although technologically it could also begin later, and/or with a significantly lower capacity), and that only an additional 50 % of the premises and storage facility will

Uz navedene pretpostavke, te procjene troškova i financijski model iz Programa, dobiju se rezultati prikazani u tablici 10.

be included 20 years later, and proportionally increase the nominal expenditures.
– In the decommissioning of the nuclear power plant, which as a whole would be postponed for 20 years, it is assumed that the nominal expenditures would increase by 50 %, more due to the unreliability of the model of prolonged financing than due to the minor contribution of eventual technical reconstruction.

Together with the aforementioned assumptions, cost estimates and the financial model from the Program, the results presented in Table 10 have been obtained.

Tablica 10 – Usporedba troškova za produženi radni vijek NE Krško
Table 10 – Comparison of the costs of the prolongation of the working lifetime of the Krško NPP

Vrste troškova / Types of expenditures		Troškovi / Expenditures (10^6 EUR)	
		Radni vijek 40 godina / Working lifetime 40 years	Radni vijek 60 godina / Working lifetime 60 years
Odlaganje NSRAO / Disposal of LILW	Nominalni troškovi / Nominal expeditures	186	372
	Diskontirani troškovi / Discounted expenditures	94	141
Odlaganje ING / Disposal of SNF	Nominalni troškovi / Nominal expeditures	568	852
	Diskontirani troškovi / Discounted expenditures	85	90
Suho skladište ING / Dry warehousing of SNF	Nominalni troškovi / Nominal expeditures	189	284
	Diskontirani troškovi / Discounted expenditures	79	98
Razgradnja NE Krško / Decommissioning of the Krško NPP	Nominalni troškovi / Nominal expeditures	206	309
	Diskontirani troškovi / Discounted expenditures	81	61
Ukupno / Total	Nominalni troškovi / Nominal expeditures	1 149	1 817
	Diskontirani troškovi / Discounted expenditures	339	390

Zbog produženja radnog vijeka NE Krško, nominalni trošak Programa povećao se za 58 %, a diskontirani samo za 15 %. No, ako se pretpostavi da će se i uplaćivanje u fondove razgradnje produžiti za 20 godina, iznos anuiteta će se značajno umanjiti.

Tablica 11 uspoređuje izdvajanja za hrvatski fond proračunata u sadašnjem Programu (koja su nešto niža od zaokruženog preporučenog iznosa) s onima koja bi se sličnim računom dobila za produženi radni vijek i razdoblje uplaćivanja, a zbog produženog razdoblja financiranja usporedba je provedena i u modelu rastućih anuiteta.

Due to the prolonged working lifetime of the Krško NPP, the nominal expenditure of the Program would be increased by 58 % and the discounted expenditure by only 15 %. However, if it is assumed that the payment into the funds for decommissioning will be prolonged by 20 years, the amounts of the annuities will be significantly lowered.

Table 11 compares the outlays for the Croatian fund computed in the current Program (which are somewhat lower than the rounded recommended amount) to those that would be obtained using similar calculations for the prolonged working lifetime and period of payment. Due to the prolonged period of financing, a comparison has also been performed in the model of escalating annuities.

Tablica 11 – Usporedba nominalnih i realnih troškova za produženi radni vijek NE Krško
Table 11 – Comparison of nominal and real expenditures for the prolongation of the working lifetime of the Krško NPP

Radni vijek / Working lifetime (broj godina / number of years)	Razdoblje utplate / Period of payment (broj godina / number of years)	Anuitet / Annuity (10^6 EUR)		Poskupljenje električne energije / Increased electricity price (EURc/kWh)
40	19	jednaki / equal	13,77	0,53
		rastući(2004) / escalating(2004)	12,97	0,50
60	39	jednaki / equal	10,82	0,42
		rastući(2004) / escalating(2004)	9,70	0,37

Iako smanjenje nominalnih izdvajanja u modelu jednakih anuiteta ne izgleda jako veliko (opterećenje po jednom kWh električne energije iz NE Krško smanjilo bi se s 0,53 na 0,42 EURcenta), realna će vrijednost uplata padati zajedno s inflacijom kroz približno dvostruko duži period nego u sadašnjem scenariju. Čak i kad bi cijena struje rasla samo po pretpostavljenoj niskoj stopi inflacije za industrijske proizvode, nominalni trošak od 0,42 EURc/kWh bio bi u posljednjem desetljeću produženog radnog vijeka na razini današnje realne vrijednosti od 0,3 EURc/kWh.

Stoga je prikladnije posljedice hipotetičkog produljenja radnog vijeka NE Krško na financiranje Programa promatrati u modelu rastućih anuiteta jednake realne vrijednosti. U tablici 11 prikazan je nominalni iznos uplata za 2004. godinu prema tome modelu pod nazivom rastući (2004). Treba napomenuti da se rastući anuitet za 2004. godinu ne razlikuje dramatično od anuiteta jednake nominalne vrijednosti samo zbog male pretpostavljene inflacije, koja vjerojatno neće biti održiva dugoročno.

Prednost korištenja modela rastućih anuiteta upravo je u tome što očiglednije prikazuje smanjenje realne vrijednosti godišnjih izdvajanja za financiranje troškova Programa (bez obzira na kretanje same inflacije). Proračunato opterećenje cijene struje iz NE Krško za 2004. godinu prema sadašnjem scenariju (0,50 EURc/kWh) smanjilo bi se u scenariju produljenog radnog vijeka za 26 % (na 0,37 EURc/kWh), a za isti postotak bile bi manje i daljnje uplate troškova razgradnje. Dakako, uplaćivanje anuiteta trebalo bi nastaviti i u periodu produljenja rada elektrane, a prikupljena sredstva pokrivala bi i vrlo konzervativno procijenjeno povećanje nominalnih troškova Programa zbog povećanja količine ING i tehnološkog NSRAO te posljedica mogućih rekonstrukcija postrojenja elektrane.

Although the reduction of the nominal allocations in the model of equal annuities does not appear very large (the surcharge per kWh of electricity from the Krško NPP would be reduced from 0,53 to 0,42 EURcenta), the real value of the payments would decline together with inflation during a period approximately twice as long as in the current scenario. Even if the price of electricity were to rise by only the assumed low rate of inflation for industrial products, the nominal expenditure of 0,42 EURc/kWh would be in the last ten years of the prolongation of the working lifetime at the level of the current real value of 0,3 EURc/kWh.

Therefore, it is more appropriate to analyze the consequences of the hypothetical prolongation of the working lifetime of the Krško NPP on the financing of the Program in the model of escalating annuities of equal real value. In Table 11, the nominal amount of payment for the year 2004 is presented according to this model under the heading of escalating (2004). It should be noted that the escalating annuity for the year 2004 does not differ dramatically from the annuity of equal nominal value, except due to the low assumed inflation that probably will not be sustainable over the long term.

The advantage of using the model of escalating annuities is that it provides a better presentation of the decline in the real value of the annual outlays for the financing of the Program costs (regardless of the trends in inflation). The calculated surcharge on electricity prices from the Krško NPP for the year 2004 according to the current scenario (0,50 EURc/kWh) would be reduced in the scenario for the prolonged working lifetime by 26 % (on 0,37 EURc/kWh), and further payments for the decommissioning expenditures would be reduced according to the same percentage. Certainly, the payment of the annuities should also continue during the period of the prolonged operation of the power plant, and the collection of monetary resources would also cover the very conservatively

Zbog konzervativnih pretpostavki u navedenoj procjeni smanjenje anuiteta nije osobito impresivno. Ako bi se za usporedbu uzeo nerealni hipotetički scenarij jednostavnog odlaganja svih aktivnosti Programa za 20 godina zbog produljenja radnog vijeka elektrane, dobio bi se proračunski iznos jednakih anuiteta od 4,69 milijuna eura umjesto 10,82 milijuna eura u opisanom realističnom i konzervativnom scenariju produljenja. Primarni razlog za tako veliku razliku nisu odnosi nominalnih troškova zbog dodatnih količina otpada, već pretpostavka o odgađanju pojedinih aktivnosti Programa u hipotetičkom scenariju.

Ipak, moguće je koncipirati i jeftin realističan scenarij Programa za produljeni radni vijek, ali on podrazumijeva različita politička usuglašavanja i odluke, pa nije prikladan za detaljno razmatranje u ovakvoj analizi. Primjera radi, moglo bi se a) odlagalište i skladište ING (50 % većeg kapaciteta) samo pomaknuti u budućnost za svih 20 godina, b) razgradnju bez poskupljenja samo pomaknuti za 20 godina, te c) odlagalište NSRAO graditi modularno tako da kapacitet 2018. godine bude pola od sada planiranog (uz npr. 70 % troška), a 20 godina kasnije izgraditi dodatak dvostruko većeg kapaciteta. Uz takve pretpostavke, proračunski jednaki anuiteti iznosili bi 7,65 milijuna eura (umjesto 10,82 milijuna eura u konzervativnom scenariju) i bili bi oko 56 % sadašnjih. Rastuće anuitete produljenje bi reduciralo na manje od polovice realne vrijednosti.

5 ZAKLJUČCI

Ukupni troškovi financiranja Programa prema sadašnjim službenim procjenama ne povećavaju cijenu električne energije toliko da ne bi i dalje ostala značajno jeftinijom od električne energije iz termoelektrana, odnosno od prosječne tržišne cijene električne energije. Za hrvatski fond razgradnje trebalo bi nisku proizvodnu cijenu (oko 2 EURc/kWh) povećati za oko 0,5 EURc/kWh (na hrvatski dio električne energije iz NE Krško).

Pouzdanost ovakve procjene troškova s tehnološkog je stajališta vrlo visoka, jer moguća odstupanja ne prelaze 20 %. Međutim, pouzdanost modela financiranja i pretpostavljenih financijskih parametara (kamata i inflacije) daleko je manja. Tu se ne mogu isključiti dugoročne promjene koje bi zahtijevale povećanje uplata reda veličine 100 %. Zbog toga je predviđeno da će se u redovitim revizijama Programa prema potrebi vršiti korekcije daljnjeg financiranja. Nije, međutim, vjerojatno

estimated increased nominal expenditures of the Program due to the increased quantity of SNF and technological LILW and the consequences of the eventual reconstruction of the existing power plant.

Due to the conservative assumptions in the stated estimate, the reduction in the annuity is not particularly impressive. If an unrealistic hypothetical scenario of the simple postponement of all the activities of the Program for 20 years due to the prolongation of the working lifetime of the power plant were used for purposes of comparison, a budgetary amount of equal annuities of 4,69 million euros would be obtained instead of the 10,82 million euros in the described realistic and conservative scenario of prolongation. The primary reason for such a great difference is not the relations of the nominal expenditures due to additional quantities of waste but the assumed postponement of the individual activities of the Program in the hypothetical scenario.

Nonetheless, it is also possible to conceive of an inexpensive realistic scenario for the Program for the prolongation of the working lifetime, but it would presume various types of political coordination and decisions and is not suitable for detailed consideration in such an analysis. For example, it would be possible a) merely to shift the repository and warehouse for SNF (50 % greater capacity) into the future for the entire 20 years, b) merely to shift the decommissioning 20 years ahead without raising the price, and c) to build the repository for LILW modularly so that the capacity in 2018 would be half of that which is currently planned (at, for example, 70 % of the cost), and to build an addition 20 years later with twice as much capacity. Together with such assumptions, the budgetary equal annuities would amount to 7,65 million euros (instead of 10,82 million euros in the conservative scenario) and would be approximately 56 % of the current ones. The escalating annuities would be reduced by the prolongation to less than half of their real values.

5 CONCLUSIONS

The total expenditures for the financing of the Program according to the current estimates do not increase the price of electricity to such an extent that it would not continue to be significantly less expensive than electricity from thermoelectric power plants, i.e. than the average market price of electricity. For the Croatian decommissioning fund, it would be necessary to increase the low production cost (approximately 2 EURc/kWh) by approximately 0,5 EURc/kWh (on the Croatian share of the electricity from the Krško NPP).

da bi čak i dva ili tri puta povećana izdvajanja za razgradnju mogla ugroziti konkurentnost cijene električne energije iz NE Krško.

Da su hrvatska izdvajanja za razgradnju počela ranije, npr. u vrijeme osnivanja slovenskog fonda, nominalna godišnja izdvajanja prema istom financijskom modelu bila bi otprilike upola manja (zahvaljujući i većoj realnoj vrijednosti istih izdvajanja u ranijim godinama), a sredstva do danas akumulirana u fondu predstavljala bi uvjerljivo jamstvo da buduća izdvajanja neće trebati dramatično uvećavati. Sličan se učinak još uvijek može postići produljenjem radnog vijeka elektrane za 20 godina, mada bi smanjenje godišnjih uplata iznosilo samo jednu četvrtinu njihove realne vrijednosti (ako se procjena vrši konzervativno, samo uz manje prilagodbe Programa).

The reliability of such estimated expenditures from the technological standpoint is very high because the potential deviation does not exceed 20 %. However, the reliability of the financing model and the presumed financial parameters (interest and inflation) is far lower. Here it is not possible to exclude long-term changes that could require an increase in the payment of an order of magnitude of 100 %. Therefore, it is anticipated that correction of the continued financing will be performed as required in the regular audits of the Program. It is not, however, likely that increasing the allocations for decommissioning by even two or three times could endanger the competitiveness of the price of electrical energy from the Krško NPP.

If the Croatian allocations for decommissioning had begun earlier, for example at the time of the establishment of the Slovenian fund, the nominal annual allocation according to the same financial model would have been approximately half as much (owing to the greater real value of the same allocations in earlier years), and the funds accumulated up to the present in the fund would have been a convincing guarantee that future allocations would not need to be increased dramatically. A similar effect can still be achieved by prolonging the working lifetime of the power plant by 20 years, although the reduction in the annual allocations would amount to only one fourth of their real value (if the estimate is performed conservatively, with only minor adjustment to the Program).

LITERATURA / REFERENCES

[1] Narodne novine – Međunarodni ugovori, broj 9/2002
[2] LOKNER, V., LEVANAT, I., RAPIĆ, A., ŽELEZNIK, N., MELE, I., JENKO, T., Program razgradnje nuklearne elektrane Krško i zbrinjavanja nisko i srednje radioaktivnog otpada i istrošenog nuklearnog goriva, ARAO/APO 2004, http://www.apo.hr
[3] Narodne novine, broj 175/2004
[4] http://www.hep.hr/publikacije/2004godisnje.pdf
[5] http://www.nek.si/hr/novinarski_centar/izvjesca
[6] http://www.eex.de
[7] LEVANAT I., LOKNER V., SUBAŠIĆ D., Scenario Development and Evaluation for the NPP Krško Revised Decommissioning Program, Proceedings of the 5th International Conference on Nuclear Option in Countries With Small and Medium Electricity Grids, Dubrovnik, 2004.
[8] Development of the site specific decommissioning plan for Krško NPP, NIS Ingenieurgesellschaft GmbH, 1996
[9] Low-Level Radioactive Waste Repositories: An Analysis of Costs, NEA, Paris, 1999
[10] Decommissioning Nuclear Power Plants: Policies, Strategies and Costs, OECD/NEA, 2003
[11] Slovenian Strategy for Disposal of Spent Fuel, McComby, 2004
[12] The Cost of High-Level Waste Disposal in Geological Repositories, OECD/NEA, 1993
[13] Internet stranica http://epp.eurostat.cec.eu

Uredništvo primilo rukopis:
2006-07-05

Prihvaćeno:
2006-09-15

Manuscript received on:
2006-07-05

Accepted on:
2006-09-15