NEKI TEMELJNI PROBLEMI PROIZVODNJE ELEKTRIČNE ENERGIJE U HRVATSKOJ U KRATKOROČNOM I SREDNJOROČNOM RAZDOBLJU

SOME OF THE BASIC PROBLEMS OF SHORT-TERM AND MEDIUM-TERM ELECTRICITY GENERATION IN CROATIA

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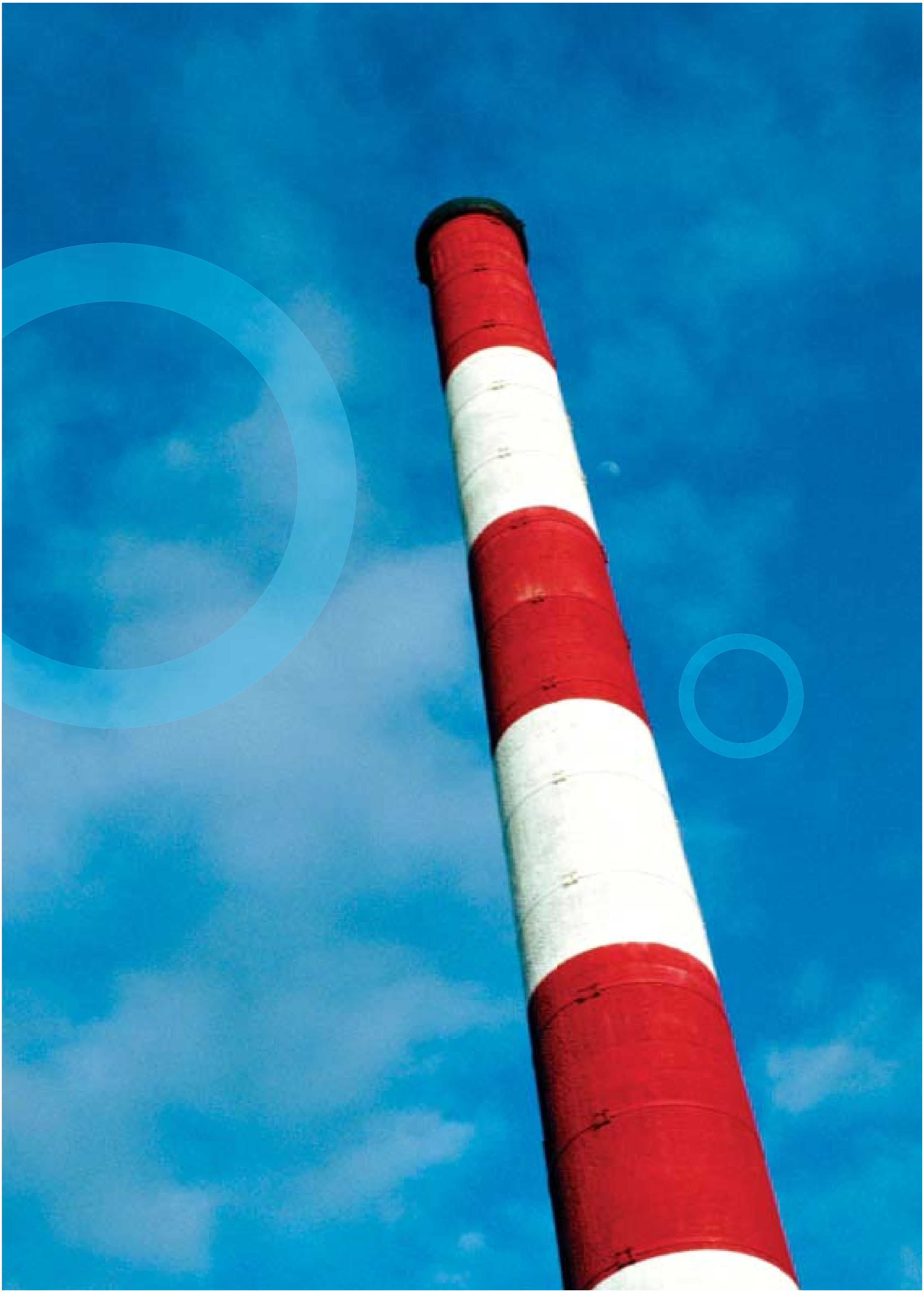
U članku se analiziraju uvjeti i ograničenja za proizvodnju električne energije u Hrvatskoj u idućem kratkoročnom i srednjoročnom razdoblju (do 2020. godine). U analizu su uključena pitanja prognoze porasta potrošnje električne energije i njezine veze s porastom bruto društvenog proizvoda, nesigurnost u raspoloživosti i cijeni prirodnog plina kao temeljnog energenta, te ograničenja u primjeni obnovljivih izvora energije. Razmotren je relativni utjecaj elektrana na okoliš, posebno u pogledu emisija stakleničkih plinova i šteta od emisija (eksterni troškovi). Izvršena je ekonomska usporedba elektrana s eksternim troškovima. Naglašen je potencijalni značaj nuklearne elektrane za Hrvatsku u srednjoročnom razdoblju te potreba diversifikacije izvora energije kao i promptnog početka pripremnih radova za sve potencijalne opcije gradnje elektrana.

The article analyzes the conditions and limitations in the generation of electricity in Croatia in the next short-term and medium-term periods (until 2020). The analysis includes the forecasts of the increase in electricity consumption and its relation to the increase in the GDP, the unstable availability and the price of natural gas as the basic source of energy, as well as limitations in the implementation of renewable resources. The article reviews the relative impact of power plants on the environment, particularly with regard to the emissions of greenhouse gases and the resulting damage (external costs). An economic comparison of power plants incl. external costs is presented. The potential importance of a nuclear power plant to Croatia in the medium term is noted, as well as the need to diversify resources and to promptly begin with the preparatory works for any potential option in building power plants.

Ključne riječi: cijene energenata, ekonomičnost elektrana, eksterni troškovi, nuklearne elektrane, planiranje potrošnje električne energije, proizvodnja električne energije u Hrvatskoj, raspoloživost prirodnog plina
Key words: availability of natural gas, cost-efficiency of power plants, electricity generation in Croatia, external costs, fuel price, nuclear power plants, planning electricity consumption



1 UVOD

U Hrvatskoj je u posljednjoj deceniji došlo ne samo do smanjenja gradnje elektrana već i do zastoja ozbiljnijih pripremih radova za takvu gradnju. S druge strane, potrošnja električne energije neprekidno raste, a glavnina postojećih termoelektrana u Hrvatskoj približava se kraju svojega radnog vijeka. Raspoloživost uvozne električne energije upitna je jer se viškovi energije u europskim zemljama smanjuju. Usporedno sa smanjenjem viškova raste cijena uvezene energije. Praksa je pokazala da deregulacija energetskog sektora, kako kod nas tako i u drugim zemljama, ne stimulira ulaganje u proizvodnju električne energije, što dovodi do sve izrazitijeg smanjenja rezervi energije u elektroenergetskom sustavu. Deregulacija, kao dio općeg procesa globalizacije, trebala bi uvesti konkurenciju u proizvodnji energije unutar elektroenergetskog sustava. Očekivani efekti deregulacije (smanjenje cijene električne energije zbog konkurentnosti elektrana), u praksi se ne mogu postići ako ona rezultira manjom ponudom električne energije od potražnje. Realno je da će se u tom slučaju dogoditi upravo obrnuto. Prosječna će cijena porasti jer će jeftiniji proizvođači, po logici tržišta, podići svoje prodajne cijene da se približe skupljima.

Postojeći hrvatski zakoni o energiji i tržištu energijom ističu poslovanje postojećeg elektroenergetskog sustava, a malo pažnje posvećuju potrebi njegova proširenja, posebno u pogledu povećanja proizvodnje električne energije.

Budući da je raspoloživost električne energije preduvjet za svekoliki gospodarski razvoj i standard stanovništva, postojeće stanje izaziva zabrinutost svih stručnjaka koji se bave energetikom.

2 POTROŠNJA I PROIZVODNJA ELEKTRIČNE ENERGIJE

2.1 Potreba za električnom energijom

Ekonomski razvoj svake zemlje vezan je uz potrošnju električne energije. Veza između stope rasta bruto društvenog proizvoda (BDP) i stope rasta potrošnje električne energije ispitana je za niz zemalja na različitim razinama ekonomskog razvoja i kod svih je ustanovljeno da je odnos tih stopa (poznat kao faktor elastičnosti) blizak jedinici. U manje razvijenim zemaljama u prosjeku je viši i bliži jedinici nego u visokorazvijenima. Valja napomenuti da je stopa promjene potrošnje električne energije u svim zemljama svijeta pozitivna. Predviđanje relativnog porasta BDP-a i potrošnje električne energije u svijetu prema prognozi Međunarodne agencije za energiju [1] prikazano je slikom 1.

1 INTRODUCTION

In the last decade, Croatia experienced a hold-up in the construction of power plants and any serious preparatory works for such a construction bogged down. On the other hand, electricity consumption is constantly rising, and most of the existing thermoelectric power plants in Croatia are nearing the end of their lifetime. Availability of imported electricity is questionable because power surpluses in European countries are dwindling and the cost of imported power is rising. It has been shown in practice that the deregulation in the energy sector, in Croatia and abroad, is not conducive to the production of electricity, which leads to an ever greater reduction in power reserves in the electricity supply system. Deregulation, as part of the universal globalisation process, was to introduce competition in power production. The expected effects of deregulation (falling prices of electricity owing to the competition between power plants) cannot be achieved in practice if deregulation results in a supply of electricity that is lower than demand. In such a case, it is only realistic to assume the opposite: the average price will go up, because cheaper vendors will follow the market logic and raise their selling prices to get closer to the more expensive vendors.

The existing Croatian legislation on energy and energy market underlines the operation of the existing electricity supply system, paying little attention to the need for its extension, particularly with a view to increasing the production of electricity.

Availability of electricity being a prerequisite to any economic development and the standard of living of the population, the present situation gives energy experts cause for concern.

2 CONSUMPTION AND PRODUCTION OF ELECTRICITY

2.1 Needs for electricity

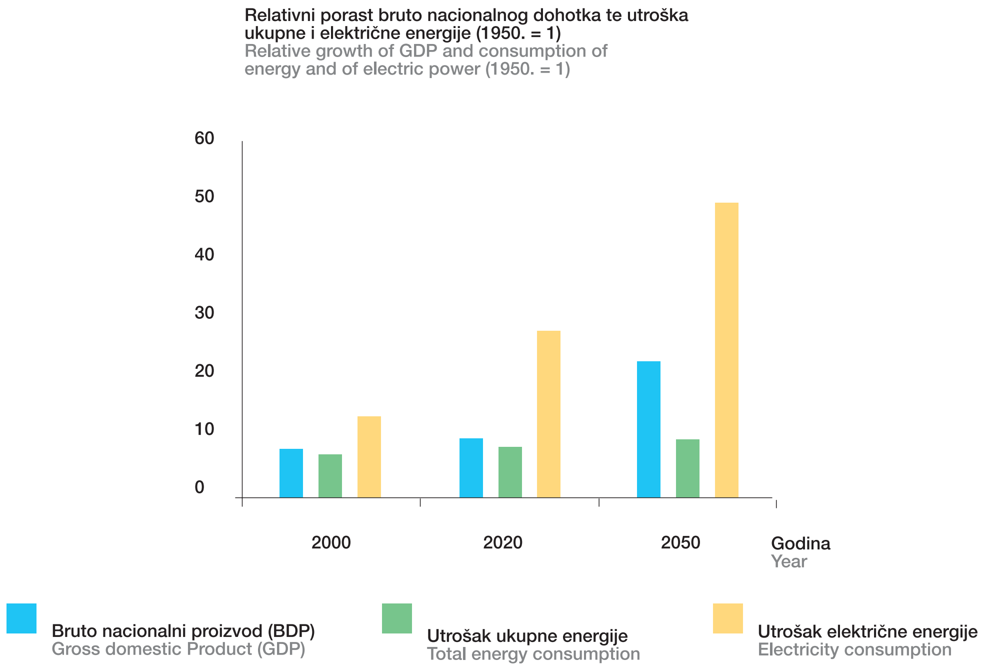
The economic development of every country is firmly related to the consumption of electricity. The relation between the GDP growth rate and the rate of growth of the consumption of electricity has been examined for a number of countries at different levels of their economic development, and it has been found in all of them that the ratio of such rates (known as flexibility rate) is close to 1. In underdeveloped economies, on the average, it is higher and closer to 1 then in developed economies. Note that the rate of change in electricity consumption in all the countries of the world is positive. The forecast of the relative growth of the GDP and electricity consumption, made by the International Energy Agency [1], is shown in Figure 1.

Iz slike 1 mogu se izvesti odnosi prosječnog porasta potrošnje električne energije i bruto nacionalnog dohotka za godine 2000. i 2020. prikazani tablicom 1.

Figure 1 allows for a derivation of relations between the average electricity consumption and the GDP increase for the years 2000 and 2020, as shown in Table 1.

Tablica 1 - Predviđeni relativni porast bruto nacionalnog dohotka i potrošnje električne energije u svijetu za razdoblje od 2000. do 2020.
Table 1 - Forecast of the relative global growth of the GDP and the increase in power consumption between 2000 and 2020

Svijet / Global	2000	2020	Prosječan porast u razdoblju od 2000. do 2020. Average increase between 2000 and 2020
BDP (rel.) / GDP (rel.), %	100	124	1,1%
Potrošnja el. energ. (rel.) / Power consumption (rel.)	100	200	3,5%



Slika 1
Očekivani relativni porast potrošnje ukupne i električne energije i bruto nacionalnog dohotka u Svijetu za razdoblje od 2000. do 2050.
Figure 1
Expected relative global increase in the consumption of energy in general and of electricity in particular, as well as the GDP growth, between 2000 and 2050

Na temelju analize niza zemalja na sličnom stupnju razvoja kao što je u Hrvatskoj dolazi se do zaključka da kod planiranja porasta potrošnje električne energije ne bi trebalo računati s nižim stopama porasta od očekivanih stopa porasta BDP-a.

Postoje, dakako, i znatne razlike između zemalja istog stupnja razvijenosti, ovisno o tome u kojoj se mjeri električna energija koristi za proizvodne i uslužne djelatnosti, a u kojoj za društveni standard i domaćinstva. O tim zakonitostima treba voditi računa i pri planiranju potrošnje električne energije u Hrvatskoj, jer se očekivana stopa rasta BDP-a u budućem razdoblju neće moći ostvariti bez odgovarajuće stope rasta potrošnje električne energije.

On the basis of the analysis of a number of countries at the same level of development as Croatia we arrive at the conclusion that in planning the growth of electricity consumption one should not count with growth rates lower that the expected GDP growth rates.

There are, of course, substantial differences between the countries at the same level of development, depending on the extent to which electricity is used in manufacturing and service sectors compared with the use related to the standard of living and household supply. This needs to be taken into account in planning the consumption of electricity in Croatia, because the expected GDP growth rate in the coming period will not be achievable without the corresponding increase in electricity consumption.

2.2 Prognoza potrošnje i proizvodnje električne energije u Hrvatskoj

Prema Strategiji razvoja energetike [2] očekivana potrošnja električne energije u Hrvatskoj u 2010. godini prema referentnom scenariju mogla bi, od sadašnjih oko 15 TWh porasti na 17,5 TWh, a u 2020. na oko 21 TWh. Iz tih podataka slijedi da se za razdoblje od 2002. do 2010. predviđa prosječna godišnja stopa porasta potrošnje električne energije oko 2 %, a za razdoblje od 2010. do 2020. oko 1,8 %. Predviđene stope porasta potrošnje električne energije vjerojatno su preniske (a ne mogu se pravdati ni vjerodostojnim analizama razvoja konzuma). Takve stope porasta dovele bi do povećanog zaostajanja Hrvatske za razvijenim zemljama i ne bi mogle podržati očekivani porast bruto društvenog proizvoda u srednjoročnom razdoblju od 3 do 5 %. Neovisno o tome, bilo bi potrebno do 2010. godine osigurati dobavu novih 2,5 TWh, a nakon toga do 2020. godine još dodatnih 3,5 TWh, odnosno ukupno oko 6 TWh električne energije.

Ako bi se povećanje potrošnje električne energije pokrilo gradnjom termoelektrana s prosječnim iskorištenjem instalirane snage od 5 000 do 6 000 h/god do godine 2010. trebalo bi, samo za pokriće povećane potrošnje, izgraditi jednu temeljnu elektranu snage 400-500 MW, a do 2020. još jednu takvu elektranu snage 600-700 MW.

Ako bi se odlučilo za skuplju varijantu i dio povećane potrošnje pokrilo gradnjom malih hidroelektrana ili elektrana koje iskorištavaju druge obnovljive izvore energije, potrebna snaga temeljnih elektrana bila bi gotovo ista ili zanemarivo manja.

Budući da je gradnja elektrana u Hrvatskoj već dugi niz godina usporena, veći je dio današnjih termoelektrana neekonomičan i zastario, pa bi one do 2020. godine trebale izaći iz redovitog pogona. To se odnosi na sve postojeće termoelektrane, osim TE Plomin 2, TE-TO Zagreb novi blok i NE Krško. Ukupna snaga jedinica koje će zastarjeti između 2010. i 2020. godine iznosi oko 1 200 MW, pa bi usporedno s gradnjom novih termoelektrana za pokriće povećane potrošnje trebalo zamijeniti i postojeće zastarjele jedinice. To znači da bi i uz navedenu vrlo skromnu stopu porasta potrošnje električne energije za pokriće konzuma do 2020. godine trebalo u Hrvatskoj izgraditi nove temeljne elektrane ukupne snage 2 200-2 400 MW.

Valja napomenuti da se rad termoelektrana na tekuće gorivo obustavlja ne samo zbog zastarjelosti opreme nego i zbog visoke cijene goriva.

Ako bi se, radi osiguranja kompatibilnosti s prognozama porasta BDP-a, prognozirala stopa porasta potrošnje električne energije u razdoblju od 2000.

2.2 Forecast of the consumption and generation of electricity in Croatia

According to the Energy Development Strategy [2] the expected consumption of electricity in Croatia in the year 2010, following the reference scenario, could rise from the about 15 TWh currently to 17.5 TWh, i.e. to about 21 TWh in 2020. It follows from this data that in the period from 2002 to 2010 the envisaged average consumption of electricity will grow at an average rate of about 2 %, or in the period from 2010 to 2020 of about 1,8 %. The envisaged growth rates for the consumption of electricity are probably too low (and they cannot be justified by reliable analyses of the development of consumption, either). Such growth rates would lead to a widening gap between Croatia and developed economies and could not support the expected growth of the GDP of 3 to 5 % in the medium term. Notwithstandingly, it would be necessary to provide the supply of another 2,5 TWh by 2010, and another 3,5 TWh by 2020, i.e. a total of about 6 TWh electricity.

If the increase in the consumption of electricity were to be covered by the construction of thermoelectric power plants with the average capacity utilisation of 5 000 to 6 000 h/year, it would be necessary to build one basic 400-500 MW power plant by the year 2010, plus another one with 600-700 MW by 2020, just to compensate the increase in consumption.

If the more expensive option were chosen to cover part of the increased consumption by the construction of smaller hydroelectric power plants or power plants utilising other renewable resources, the required capacity of the basic power plants would still be almost the same or insignificantly smaller.

Considering that the construction of electric power plants in Croatia has only been dragging for a number of years now, most of the existing thermoelectric power plants are not cost effective and are obsolete and should be decommissioned by 2020. This applies to all the existing thermoelectric power plants, except Plomin 2, the New Unit of the Zagreb Power/Heat Plant, and the Krško nuclear power plant. The total capacity of the units which will become obsolete between 2010 and 2020 is about 1 200 MW, so simultaneously with the construction of new thermoelectric power plants to cope with the increasing consumption, the existing obsolete units should also be replaced. This means that even with the above-mentioned very modest rate of growth of electricity consumption by 2020, Croatia should build new basic power plants with their capacity totalling 2 200-2 400 MW.

Thermoelectric power plants burning liquid fuel are to be decommissioned not only because they have become obsolete but also because of high fuel prices.

If in keeping with the forecasts of BDP growth we predict 4% increase in the consumption of electricity from 2000 to do 2020. godine od 4 %, konzum u 2020. godini dosegao bi oko 27 TWh. To znači da bi gradnjom novih elektrana do te godine trebalo pokriti potrošnju od 12 TWh. Time bi potrebna snaga novih temeljnih elektrana u 2020. godini bila za oko 1 000 MW veća od navedene, dakle u granicama 3 200-3 400 MW.

2.3 Pravni i organizacijski preduvjeti za realizaciju programa gradnje elektrana u Hrvatskoj

Nakon utvrđivanja potrebe gradnje novih elektrana u Hrvatskoj postavlja se pitanje o odgovornom subjektu za realizaciju tog cilja. Nakon reorganizacije HEP-a i deregulacije sektora proizvodnje električne energije izgubljena je prijašnja nedvojbena odgovornost elektroprivrede za gradnju elektrana i osiguranje sigurnog snabdijevanja potrošača električnom energijom. To bi posebno došlo do izražaja nakon eventualne privatizacije HEP-a.

Neosporno je da Vlada RH ostaje odgovorna za funkcioniranje svih mehanizama države pa tako i za snabdijevanje električnom energijom. Logika tržišnog poslovanja da proizvodnju bilo koje robe određuje zakon ponude i potražnje što, preneseno na elektroprivredu, znači da ekonomski interes investitora treba odrediti odabir elektrane, vrijeme početka proizvodnje i količinu proizvedene električne energije. Cijenu bi trebao odrediti odnos ponude i potražnje bez upletanja države, a regulator cijene trebala bi biti očekivana konkurencija među proizvođačima električne energije.

Takve su postavke nekompatibilne s nedvojbenom obvezom državne uprave da osigura bitne uvjete za život i funkcioniranje cijelog društva, od kojih je opskrba električnom energijom jedan od najvažnijih. Nezaobilazna je uloga države i kada je riječ o cijeni proizvedene energije (posebno ako ne postoji dovoljna ponuda na tržištu i ravnopravan pristup izvorima enegije svih potrošača). Budući da je riječ o proizvodu od velike važnosti za društvo, potpuno slobodno formiranje cijene električne energije po tržišnim uvjetima (posebno u uvjetima pomanjkanja konkurentne proizvodnje), ugrozilo bi standard stanovništva i obustavilo rad niza poduzeća, pa je intervencija države prijeko potrebna bez obzira na to što narušava logiku tržišnih uvjeta privređivanja.

U praksi se pokazalo, da su privatni investitori slabo zainteresirani za ulaganje u gradnju elektrana. Rentabilnost je gradnje rizična, s jedne strane zbog moguće intervencije državne regulative, javnosti, političkih stranaka (primjer je nesigurnosti investitora niz obustavljenih priprema za gradnju elektrana u Hrvatskoj), a s druge strane zbog nesigurna povrata kapitala i nesigurna profita zbog mogućeg direktnog ili indirektnog utjecaja države na cijenu proizvedene energije.

2020, the consumption would total about 27 TWh in 2020. This means that the construction of new power plants would have to account for the consumption of 12 TWh. The required capacity of new basic power plants in 2020 would thus be about 1 000 MW greater than mentioned above, i.e. between 3 200 and 3 400 MW.

2.3 Legal and organisational requirements for the realisation of the programme of construction of electric power plants in Croatia

Once we have agreed on the necessity to build new electric power plants in Croatia, the next question is who is to be the responsible facilitator. Following the re-organisation of HEP and the deregulation of the sector of electric power generation, the former clear responsibility of electric power utility to build power plants and provide stable supply is gone. This would become particularly visible in case of the privatisation of HEP.

It is undisputable though that Croatian Government remains responsible for the operation of all mechanisms of the state, including the electricity supply. The market logic postulates that the production of any goods is determined by demand and supply which, in terms of the electric power utility, means that the economic interest of the investor should determine the choice of the plant, the starting time of commission and the quantity of the electricity produced. The price should be determined by the relation between the demand and the supply without any intervention by the state, with the expected competition between electricity producers acting as price corrector.

Such assumptions are incompatible with the undisputed obligation of the government to secure the essentials for the life and functioning of the society at large, among which the electricity supply is one of the most important. The role of the state is also unavoidable when it comes to the price of the electricity generated (particularly if there is no sufficient market supply and an equal access to energy sources for all consumers). Being a product of great importance for the society in general, totally free pricing of electricity under market conditions (particularly when there is no competition) would jeopardise the standard of living of the population and terminate the operation of a number of companies, so intervention by the state is necessary although it goes against the logic of the market economy.

It has been shown in practice that private investors do not care much for investing in the construction of power plants. Profitability of the construction is questionable because of the possible state regulatory intervention, the reaction of the public, political parties (an example of the insecurity of investors is a number of halted preparations for the construction of electric power plants in Croatia) on the one hand, and because of the uncertain return on investment and profit owing to a possible direct or indirect interference of the state with the price of electricity, on the other.

Navedeni problemi (koji su prisutni općenito, a ne samo u Hrvatskoj) traže kompromis između proklamiranih tržišnih uvjeta i potrebne intervencije države. Kompromis je ugrađen u naše zakonodavstvo (Zakon o energiji [3], Zakon o tržištu električnom energijom [4]). Usvojena Strategija energetskog razvitka Hrvatske [5] u osnovi je samo jedna od vizija zamišljenoga budućeg razvoja energetike u tri scenarija, a ne podloga za operativne planove. S druge strane, Odluka o donošenju programa prostornog uređenja Republike Hrvatske [6] ima neposredan (ali neopravdano nepovoljan) utjecaj na srednjoročne planove gradnje elektrana u Hrvatskoj, jer ne dopušta čak ni studijske i pripremne radove za gradnju termoelektrana na ugljen i nuklearnih elektrana prije 2015. godine.

Zaključak je razmatranja zakonskih podloga za gradnju elektrana u Hrvatskoj da se postojeći zakoni uglavnom bave poslovanjem postojećeg sustava i da daju veoma malo osnova za pokretanje njegova razvoja, posebno kada je riječ o proizvodnji električne energije.

Budući da je snabdijevanje električnom energijom od suštinskog značaja ne samo za gospodarstvo nego i za standard građana, tom problemu svi mjerodavni organi države trebaju posvetiti punu pozornost, jer je riječ ne samo o prioritetnom gospodarskom nego i političkom pitanju.

3 RASPOLOŽIVOST ENERGETSKIH IZVORA ZA PROIZVODNJU ELEKTRIČNE ENERGIJE

Glavninu pokrića povećane potražnje električne energije u Hrvatskoj u idućem kratkoročnom razdoblju (do 2010. godine) treba zasnivati na vrlo ograničenim domaćim izvorima energije, gradnji elektrana uz korištenje uvoznih energenata i uvozu električne energije.

3.1 Vlastiti izvori energije

Zbog vrlo ograničenih vlastitih zaliha fosilnih goriva, kao vlastiti energetski izvori za proizvodnju električne energije u Hrvatskoj preostaju tradicionalni obnovljivi izvori (velike i male hidroelektrane) i neki od tzv. novih obnovljivih izvora energije (sunčana energija, energija vjetra, energija biomasa i ponegdje geotermalna energija).

Hidroelektrane

Razvoj iskorištavanja hidroenergije u Hrvatskoj gradnjom velikih i malih hidroelektrana ograničen je preostalim kapacitetima vodenih tokova i

The problems presented (which are universal and not only specific to Croatia) require a compromise between the proclaimed market criteria and the necessary intervention by the state. The compromise is built into our legislation (Energy Act [3], Law on Electricity Market [4]). The adopted Strategy for the Development of the Energy Sector of Croatia [5] is basically one of the visions of the future development of the energy sector according to three scenarios, not a basis for operative plans. On the other hand, the Decision on the Adoption of the Physical Planning Program of the Republic of Croatia [6] has a direct (unreasonably unfavourable) effect on the medium-term plans for the construction of electric power plants in Croatia, because it does not allow even to undertake studies or preparatory works for the construction of coal-fired thermoelectric power plants and nuclear power plants prior to the year 2015.

The legislative basis for the construction of electric power plants in Croatia leads to the conclusion that the laws in place mostly deal with the operation of the existing system, providing very little basis for initiating the development of the same, particularly when it comes to the production of electricity.

Electricity supply being essential not only to the economy but also to the standard of living of the population, all the relevant authorities need to pay full attention to it, because it is a priority economic issue and a political issue as well.

3 AVAILABILITY OF ENERGY SOURCES FOR THE PRODUCTION OF ELECTRICITY

Covering most part of the increase in demand for electricity in Croatia in the next short-term period (by 2010) is expected to be based on the very limited national energy sources, the construction of electric power plants utilising imported fuel, and the import of electricity.

3.1 Own energy resources

Because of the very limited national reserves of fossil fuels, Croatia's own potential for producing electricity includes the traditional renewable resources (large and small hydroelectric power plants) and some of the so-called new renewable sources of energy (solar energy, wind energy, biomass energy and, occasionally, geothermal energy).

Hydroelectric power plants

The development and utilisation of hydro energy in Croatia through the construction of large and small hydroelectric power plants is limited by the remaining capacity of water flows and the availability of environmentally acceptable sites for the construction of such facilities, particularly the ones whose construction would also be economically justifiable. According to the HEP Development Plan (Master Plan) [2] the construction of several large and raspoloživošću ekološki prihvatljivih lokacija za gradnju tih objekata, posebno onih kojih bi gradnja bila i ekonomski opravdana. Prema planu razvoja HEP-a (Master Plan) [2] predviđena je gradnja nekoliko većih i manjih hidroelektrana (Novo Virje, Podsused, Čaprazlije, Drenje, Lešće, Krčić) namjena kojih je šira od same proizvodnje električne energije (zaštita od poplava, uređenje obala, navodnjivanje), pa je njihova realizacija osim zadovoljavanja ekonomskih i ekoloških kriterija te prihvaćanja javnosti uvjetovana i usuglašavanjem zainteresiranih partnera u gradnji objekata.

Novi obnovljivi izvori energije

Novi obnovljivi izvori električne energije (tim terminom, kojim su označeni svi obnovljivi izvori osim većih hidroelektrana, često se nazivaju i aditivni izvori energije kako bi se naglasilo da sami ne mogu udovoljiti zahtjevima konzuma) razvili su se za primjenu u elektroenergetici tijekom 1970-ih godina. Razvoj je počeo u SAD-u radi dobivanja izvora električne energije bez atmosferskih emisija i koji neće imati probleme što prate primjenu nuklearne energije (među kojima je glavna briga bila mogućnost proliferacije nuklearnih materijala). Za proizvodnju električne energije u Hrvatskoj u obzir mogu doći elektrane koje iskorištavaju energiju sunca, vjetra i biomasa.

Sunčane i vjetrene elektrane

U prvim godinama razvoja novih obnovljivih izvora energije najveće su nade polagane u solarne termičke sustave SEGS s paraboličnim pločama snage do 80 MW (SEGS i- VIII) koji su se gradili u Kaliforniji, a nešto manje u sustave s centralnim tornjem. Nakon smanjenja državnih subvencija obustavljena je proizvodnja sustava SEGS. U zemljama Srednje Europe zbog velikog udjela difuzne komponente u Sunčevu zračenju ne dolazi u obzir gradnja termičkih solarnih sustava nego samo onih s fotoelektričnim panelima.

Usporedno s razvojem sunčanih sustava analizirana je i mogućnost korištena energije vjetra. Te su analize pokazale da se na povoljnim lokacijama (u Europi su to prvenstveno one na obali Atlantika) primjenom vjetroelektrana može postići znatno bolja ekonomičnost proizvodnje električne energije od korištenja fotoelektričnih panela. Zbog toga kada se danas govori o obnovljivim izvorima za proizvodnju električne energije uglavnom se misli na vjetroelektrane. Unatoč tomu, ni gradnja tih elektrana nije ekonomski održiva bez subvencija države.

Temeljni problem pri korištenju energije vjetra nije samo u kratkom prosječnom vremenu korištenja instalirane snage (oko 20 %), nego i u činjenici da je proizvodnja energije podložna nepredvidljivim i brzim vremenskim promjenama. Brzina promjena

small hydroelectric power plants has been envisaged (Novo Virje, Podsused, Čaprazlije, Drenje, Lešće, Krčić) whose purpose is broader than just to generate electricity (flood protection, regulating river banks, irrigation), and their realisation, in addition to meeting the economic and environmental criteria and the public acceptance, is also subject to the harmonisation between the partners holding a stake in the construction of the facility.

New renewable resources

New renewable resources (the term covering all the renewable resources except major hydroelectric power plants, is often used to also denote additive resources, emphasising that they cannot meet the consumption requirements alone) were developed for the electric power sector during the 1970s. Their development began in the U.S.A. with a view to obtaining a source of energy without atmospheric emissions and the issues raised by the utilisation of nuclear energy (among which one of the main concerns was the possibility of proliferation of nuclear materials). What comes in question for electricity production in Croatia are power plants harnessing the energy of the sun, wind and biomass.

Solar and wind power plants

In the first years of the development of renewable resources, the biggest hope were solar thermal system, SEGS, with parabolic troughs and the capacity of up to 80 MW (SEGS i- VIII), built in California, and to a lesser extent the central tower system. Following the reduction in government subsidies the manufacture of the SEGS system was stopped. In Central European countries, because of the great share of the diffuse component in the solar irradiation, the construction of thermal solar systems is out of the question, only of those with photoelectric panels.

Simultaneously with the development of solar systems, the potential for harnessing wind was also analysed. Analyses showed that at favourable sites (in Europe these are primarily located at the Atlantic coast) wind power plants can achieve a much better cost effectiveness for power generation than using photoelectric panels. Today, speaking of renewable resources for the generation of electricity we usually mean wind power plants. However, the construction of such power plants is also economically not feasible without government subsidies.

The basic problem with harnessing the energy of the wind is not only the short average time of utilisation of the capacity (about 20 %), but also the fact that the production of electricity is subject to unforeseeable and quick weather changes. The changes in the generation of electricity are much quicker in wind power plants than in solar power plants (adding to the unpredictability of production). Satisfactory consumer supply in a system with wind power plants can only be achieved if along with such power plants there is also a reliable and flexible source of energy (such as a gas power plant or an accumulation dam-type proizvodnje energije (a time i nepredvidljivost proizvodnje energije) kod vjetroelektrana je veća nego kod Sunčevih elektrana. Zadovoljavajuće snabdijevanje potrošača u sustavu koji sadrži vjetroelektrane može se postići samo ako uz te elektrane postoji pouzdan i fleksibilan izvor energije (kao što je plinska elektrana ili akumulacijska hidroelektrana) koji u svakom trenutku može zamijeniti proizvodnju energije vjetroelektrane.

Jedna je od teškoća u gradnji vjetroelektrana zauzimanje velikih površina zemljišta. Primjerice, analizom je pokazano da bi povećanje udjela proizvodnje električne energije u elektranama na vjetar u Njemačkoj na 10 % dovelo do zauzimanja 2 % cijelog teritorija te države. Valja napomenuti da je otpor javnosti prema gradnji vjetroelektrana, zbog narušavanja krajolika, sve veći, pa se u mnogim slučajevima u Zapadnoj Europi njihova gradnja planira na morskoj pučini (Off Shore). Danas je u Europi gradnja takvih elektrana najzastupljenija u Njemačkoj. To treba shvatiti kao napor da se u toj zemlji, u uvjetima kada su ostale mogućnosti gradnje elektrana, osim iskorištenja uvoznog plina, veoma ograničene ili nedopuštene (gradnja termoelektrana na ugljen i gradnja nuklearnih elektrana), i bez obzira na ekonomičnost, osigura bilo kakva vlastita proizvodnja električne energije koja je donekle prihvatljiva u javnosti. Nadalje, znatni državni poticaji proizvođačima opreme za vjetroelektrane u industrijski razvijenim zemljama te povoljni krediti za gradnju takvih elektrana investitorima bi trebali osigurati njihovu konkurentnost, osobito na tržištima zemalja u razvoju. Takvim se pristupom znatno ograničava mogućnost razvoja lokalnih proizvođača opreme za te elektrane. A upravo se učešće lokalne industrije navodi kao jedan od razloga za gradnju elektrana s obnovljivim izvorima energije u nerazvijenim zemljama, uključujući i Hrvatsku.

Iskorištavanjem novih obnovljivih izvora energije smanjuje se potrošnja goriva u termoelektranama ili vode iz spremnika akumulacijskih hidroelektrana. Ekonomičnost iskorištavanja tih izvora energije ovisi o cijeni zamjenskoga fosilnoga goriva (porastom cijene plina raste rentabilnost obnovljivih izvora energije) i o cijeni gradnje elektrane s obnovljivim izvorom energije.

Uključenjem većeg udjela vjetroelektrana u elektroenergetski sustav znatno se otežava regulacija snage i frekvencije zbog njihove nepredvidljivo varijabilne izlazne snage, nepovoljno se utječe na prijenosnu mrežu i ekonomičan rad termoelektrana.

Elektrane koje iskorištavaju biomasu

Često se spominje od obnovljivih izvora energije biomasa. Svrstavanje biomasa u obnovljive izvore energije polazi od ideje da elektrane spaljuju raslinje

hydroelectric power plant) which can at any moment substitute the power generation of the wind power plant.

One of the problems in the construction of wind power plants is that they occupy large areas of ground. An analysis has show, for example, that increasing the share of wind power plants in generating electricity in Germany to 10 % would lead to the occupation of 2 % of the territory of that country. It should also be mentioned that the opposition of the public to the construction of wind power plants is growing, because they dominate the landscape, so in many cases their construction in Europe is planned offshore. Today, the construction of wind power plants is mostly taking place in Germany. This should be seen as an effort to secure, regardless of cost efficiency, any publicly acceptable electric power production in the country in which other options, except the utilisation of imported gas, are very limited or not allowed (construction of coal-fired thermoelectric power plants and nuclear power plants). Substantial government subsides to the manufacturers of the equipment for wind power plants in industrial countries, and favourable loans for their construction, should secure their competitiveness, particularly on the markets of developing countries. Such an approach considerably limits the possibilities for the development of local manufacturers of equipment for wind power plants. It is precisely the participation of local industry that is one of the reasons for the construction of power plants utilising renewable sources of energy in underdeveloped countries, including Croatia.

Utilisation of renewable sources of energy reduces the consumption of fuel in thermoelectric power plants or of the water in the reservoirs of hydroelectric power plants with accumulation dams. Cost effectiveness of the utilisation of such sources depends on the price of the substitute fossil fuel (when the price of gas goes up, so does the cost effectiveness of renewable sources) and on the cost of construction of power plants using renewable sources.

The inclusion of a larger number of wind power plants in the electricity supply system makes the regulation of power and frequency considerably more difficult because of their unpredictably variable output, affecting the transmission network and economic operation of power plants.

Electric power plants utilising biomass

Biomass is often mentioned as a renewable source. Including biomass in renewable sources starts from the assumption of power plants burning vegetation they themselves grow so as to annul the burning CO_2 emissions through absorption (in the vegetation grown). Considering many examples of biomass utilisation it is hard to justify the realisation of such an idea.

Compared with traditional sources, low-energy biomass (farming refuse, saw mill refuse, community refuse, dedicated plantation vegetation) is used to generate heat in koje uzgajaju tako da se djelovanje emisija CO_2 zbog izgaranja i apsorpcije (u uzgojenom raslinju) međusobno poništava. U mnogim primjerima iskorištavanja biomasa teško je pravdati realiziranje takve ideje.

Biomasa je u usporedbi s klasičnim energentima niskokalorični izvor energije (poljoprivredni otpadci, otpadci pilana, komunalni otpad, plantažno uzgajano raslinje) od kojeg se u specijalnim kotlovima proizvodi toplinska energija, a ona se upotrebljava za proizvodnju električne energije slično kao u svakoj termoelektrani. U svijetu postoji nekoliko prototipnih postrojenja za iskorištavanje biomasa [7]. Najveći je problem u osiguranju dovoljne količine goriva po prihvatljivoj cijeni za cijeli radni vijek elektrane. Jedna je od mogućnosti u iskorištavanju komunalnog otpada većih gradova.

Prognoza udjela novih obnovljivih izvora energije u elektroenergetici Hrvatske

Na osnovi današnjeg stanja razvoja iskorištavanja sunčane energije, vjetra i biomasa u proizvodnji električne energije može se zaključiti da udio novih obnovljivih izvora energije u podmirenju budućih potreba za električnom energijom u Hrvatskoj neće biti značajan. Isto je tako sigurno da bi forsiranje njihova znatnijega korištenja povećalo proizvodne cijene električne energije. Stoga bi obvezu uključenja obnovljivih izvora u elektroenergetiku u okviru pregovora s EU trebalo nastojati smanjiti. Suglasno tomu nerazumljiva je eksplicitna tvrdnja sadržana u Zakonu o energiji (članak 14) [3] da je iskorištavanje obnovljivih izvora u interesu Republike Hrvatske.

Stupanj uključenja domaće industrije u taj proces ovisiti će o konkurentnosti ponude, državnim poticajima i uvjetima financiranja gradnje.

3.2 Gradnja elektrana koje iskorištavaju uvozne energente

Ključno rješenje za podmirenje potrošnje električne energije u Hrvatskoj u bližoj je budućnosti gradnja termoelektrana na uvozna fosilna goriva. Radi bliže analize takve gradnje treba se osvrnuti na karakteristike tih goriva s aspekta sigurnosti dobave i ekonomičnosti iskorištavanja.

Ugljen

Energetska vrijednost utvrđenih zaliha ugljena u svijetu (42 000 EJ) znatno je daleko veća od energetske vrijednosti zaliha drugih fosilnih goriva (6 100 EJ plin i 5 900 EJ tekuća goriva).

Potrošnja ugljena, unatoč velikim zalihama manja je od potrošnje plinovitih i tekućih goriva, a trend relativnog smanjivanja potrošnje ugljena nastavit će se, prema predviđanjima, i u budućnosti. Zbog toga

special boilers which is then used to generate electricity as in any other thermoelectric power plant. There are several prototype facilities world-wide utilising biomass [7]. The biggest problem is how to provide sufficient quantity of fuel at acceptable price throughout the lifetime of the power plant. One of the possibilities lies in utilising community refuse of major cities.

Prediction of the share of new renewable sources in the electric power supply of Croatia

On the basis of the current development of utilisation of solar power, wind and biomass in generating electricity it can be concluded that the share of new renewable sources in meeting the future needs for electricity in Croatia will not be significant. It is also quite certain that insisting on their more intensive use would increase the production costs of electricity. For this reason, in the negotiations with the EU efforts should be made to minimise the obligation to include renewable sources in the electricity supply system. In that context, the explicit statement in the Energy Act (Article 14) [3], that utilising renewable sources is in the interest of the Republic of Croatia, is absolutely incomprehensible.

The extent of inclusion of local industry in the process will depend on how competitive their bids are, on the government subsidies and on the conditions for financing the construction.

3.2 Construction of power plants utilising imported fuels

The key solution to electricity supply in Croatia in the near future is to build thermoelectric power plants burning imported fossil fuels. For a closer analysis of such a solution it is necessary to review the characteristics of such fuels in terms of their stability of supply and cost effectiveness.

Coal

The energy value of the world's coal reserves (42 000 EJ) substantially exceeds the energy value of the reserves of other fossil fuels (6 100 EJ gas and 5 900 EJ liquid fuels).

The consumption of coal, in spite of the great reserves, is lower than the consumption of gas and liquid fuels, and the trend of a relative decrease in consumption will also continue in the future, according to predictions. Consequently, availability of coal as fuel for electricity production is not questionable. The preferred type of coal for this purpose is coal with high energy value (pit coal/anthracite) and low in sulphur content (1-2 % or less).

The price of coal per unit of energy value is approximately half the price of gas: 1,8-2,2 USD/GJ (or 40-50 USD/t). On the other hand, the efficiency of conversion of heat into mechanical energy in a coal-fired plant is by about one third lower than in a gas-fired plant with a combined raspoloživost ugljena kao energenta za iskorištavanje u elektroenergetici nije upitna. Za uporabu se preferira ugljen visoke kalorične vrijednosti (kameni ugljen) i s malim sadržajem sumpora (1-2 % ili niže).

Cijena ugljena po jedinici energetske vrijednosti približno je polovica od cijene plinovitoga goriva i iznosi 1,8-2,2 USD/GJ (odnosno 40-50 USD/t). S druge strane, učinkovitost pretvorbe toplinske energije u mehaničku kod termoelektrane na ugljen za oko trećinu je niža nego kod termoelektrana koje iskorištavaju plinovito gorivo u kombinirano plinsko-parnom ciklusu (približno 42 % za termoelektranu na ugljen i do 62 % za termoelektranu na plin).

Nepovoljni su aspekti gradnje termoelektrane na ugljen u odnosu na termoelektranu na plinovito gorivo u kombiniranom ciklusu: 2,5-3 puta viši investicijski troškovi (1 400-1 600 USD/kW za termoelektranu na ugljen u odnosu na 450-650 USD/kW za plinsku elektranu s kombiniranim ciklusom) i izrazitiji utjecaj na okoliš zbog veće emisije krutih čestica, sumpornog i ugljičnog dioksida u atmosferu. U investiciju termoelektrane uključeni su i troškovi postrojenja za odstranjivanje sumpornih (a kadkad i dušikovih) oksida te krutih čestica iz dimnih plinova do mjere koja zadovoljava domaće, odnosno europske propise.

Pri planiranju gradnje novih termoelektrana na ugljen u Hrvatskoj trebalo bi razmotriti i oportunost primjene novih tehnologija gradnje tih elektrana (izgaranje u fluidiziranom sloju - FBC), te integralno rasplinjavanje ugljena, (IGCC) koje predviđaju znatno smanjenje atmosferskih emisija s lokalnim i regionalnim djelovanjem (krute čestice, sumporni i dušikovih oksidi). Nadalje, mogućnost poboljšanja učinkovitosti pretvorbe toplinske energije i smanjenje emisija po jedinici proizvedene električne energije postiže se i primjenom visokih parametara pare (nadkritični parni ciklus).

Visina investicije termoelektrana na ugljen u kojima su primijenjene nove tehnologije neće se bitno razlikovati od investicija za klasična postrojenja.

Jedna od razlika između termoelektrane na ugljen i plinske elektrane način je uskladištenja i dopreme goriva do lokacije. Termoelektrane na ugljen, koje moraju upotrebljavati uvozni ugljen, a on u Hrvatsku može stići uglavnom morskim putem, najprikladnije je locirati na morskoj obali. Pritom se mogu očekivati teškoće u dobivanju lokacijske dozvole zbog otpora turističkih organizacija i javnosti.

Lokacija na morskoj obali ima prednost i zbog odvoda otpadne topline (koja kod termoelektrane na ugljen iznosi oko 60 % proizvedene toplinske energije u kotlu). Izravno hlađenje budućih većih

gas-steam cycle (approximately 42 % in coal-fired plant compared with up to 62 % in gas-fired plant).

The aspects of the construction of a coal-fired thermoelectric power plant compared with a gas-fired plant with a combined cycle are unfavourable: 2,5-3 times higher investment cost (1 400-1 600 USD/kW for coal compared with 450-650 USD/kW for gas) plus heavier environmental impact due to greater emissions of solid particulates, sulphur and carbon dioxide in the atmosphere. The amount of investment includes facilities for the removal of sulphur (sometimes also of nitrogen) oxides and solid particulates from flue gases to meet national i.e. European requirements.

In planning the construction of new coal-fired thermoelectric power plants, Croatia should consider the implementation of new technologies (fluidised-bed combustion (FBC) and integrated gasification combined cycle (IGCC)) to provide for a considerable reduction in atmospheric emissions with local and regional impact (solid particulates, sulphur and nitrogen oxides). Furthermore, a possibility for improving the efficiency of heat conversion and reducing emissions per unit of electric power generated can also be achieved through the application of high-level steam parameters (supercritical steam cycle).

The level of investment in a coal-fired thermoelectric power plant in which new technologies are applied will not differ essentially from the investment in a traditional facility.

One of the differences between coal-fired and gas-fired plants is the manner in which fuel is transported to the location and stored. Thermoelectric power plants which have to use imported coal, which in Croatia can mainly be transported by sea, are best located on the coast. In this respect, one can expect difficulties with obtaining site clearance because of the opposition of tourist organisations and the public.

Location on the coast has also the advantage with regard to the dissipation of waste heat (which in coal-fired plant is about 60 % of the heat generated in the boiler). Consistent with the European practice, direct (freshwater) cooling of future major thermoelectric power plants (or nuclear power plants) by river water is not a feasible option in Croatia. The only solution is to fully utilise recirculation cooling towers. Waste heat could also be reduced in a co-generation process. A prerequisite to this is the existence of heat consumers and a built heat transmission network, which is hard to achieve in many of the locations.

Gas as fuel

Gas as fuel is superior to coal and for that reason much more expensive. The price of gas was traditionally related to the price of oil, but this does not have to be a rule for the future.

termoelektrana (ili nuklearnih elektrana) riječnim vodotocima u Hrvatskoj je, sukladno europskoj praksi, teško ostvarivo. Jedino je rješenje povratno hlađenje rashladnim tornjevima u punom iznosu. Otpadna toplina mogla bi se smanjiti u slučaju mogućnosti primjene kogeneracijskog procesa. Uvjet je za to postojanje toplinskoga konzuma i izgrađene toplinske mreže, što se kod mnogih lokacija teško može ostvariti.

Plinovito gorivo

Plin je kao gorivo superiorniji od ugljena i zbog toga znatno skuplji. Cijena plina tradicionalno se vezivala uz cijenu nafte, iako to ne mora biti pravilo za budućnost.

Zbog prednosti plina kao energenta njegova je potrošnja šira od potreba elektroenergetike. Upotrebljava se u industriji i domaćinstvima, a ti potrošači imaju obično prioritet pred elektroenergetikom jer teže mogu supstituirati energent i podnose višu cijenu. Zbog toga ne treba zaboraviti da su zalihe plina raspoložive za elektroenergetiku znatno manje od ukupnih zaliha tog energenta. S toga gledišta plinovito se gorivo razlikuje od ugljena jer je primjena ugljena izvan elektroenergetike mnogo manja. Valja naglasiti da su stvarne zalihe energenata ograničene ekonomskim pokazateljima iskorištavanja, a ne njihovim fizičkim zalihama u Zemljinoj kori. Zato je vjerojatno da se ukupne zalihe nekih od njih (u prvom redu ugljena) nikada neće iskoristiti.

Hrvatska dio potrošnje plina pokriva iz vlastitih izvora, a dio iz uvoza, s tim što će buduće povećanje potrošnje moći pokriti jedino dodatnim uvozom. Očekuje se postupno smanjenje vlastite proizvodnje plina, tako da će udio uvoza već u 2010. godini (kada će ukupna potrošnja dosegnuti oko 3,8 milijardi m^3) iznositi 30 %. Daljim povećanjem potrošnje plina (koja bi 2030. godine u Hrvatskoj trebala dosegnuti razinu od 5-6 milijardi m^3 godišnje) morati će se i uvoz znatnije povećati (na barem 50 % potrošnje).

Zalihe prirodnog plina u svijetu su izrazito neravnomjerno raspoređene (u tom se pogledu plin razlikuje od ugljena). Prema IEA [1] oko 70 % dokazanih svjetskih zaliha plina (164 Tm^3) nalazi se na području Rusije i Bliskog istoka (56,7 i 58,5 Tm^3). Glavna središta potrošnje tog energenta, Zapadna Europa i Sjeverna Amerika, raspolažu s znatno manjim zalihama (7,7 Tm^3 i 6,4 Tm^3, odnosno 4,7 % i 3,9 % svjetskih zaliha). S nekonvencionalnim zalihama plina (hidrati) zbog nepoznatih uvjeta eksploatacije i cijene danas se ne računa. U pogledu mogućnosti dobave prirodnog plina Zapadna Europa u prednosti je pred Sjevernom Amerikom, jer je dobava potencijalno moguća plinovodima iz najvećih nalazišta. Očekivana razlika između potrošnje i proizvodnje plina u europskim zemljama koje pripadaju grupaciji OECD

The advantages of gas as a source of energy allow for its being used more widely than just in electricity generation. It is also used in industry and in households, and these consumers usually have the priority over electricity generation because it is much more difficult for them to find a substitute for the source of energy, and because they accept higher prices more readily. Note that gas supplies available for electricity generation are considerably lower than the total reserves of this resource. In this, gas differs from coal, because the use of coal beyond electricity generation is much more limited. Actual supplies of the sources of energy are limited by the economic indicators of their utilisation and not by their physical reserves in Earth's crust. It is, therefore, probable that the total reserves of some sources of energy (primarily of coal) will never be exhausted.

Croatia covers part of its gas consumption from its own sources and part of it from the import, so the future consumption will only be possible to cover by additional import. Croatia's own production of gas is expected to go down, so that already in 2010 (when the total consumption will reach about 3,8 billion m^3) its share will only be 30%. Further increase in the consumption of gas (5-6 billion m^3 per year by 2030) means considerable increase in the import (to at least 50 % of the consumption).

Natural gas reserves throughout the world are very unevenly distributed (in this, too, gas differs from coal). According to IEA [1] about 70 % of documented global reserves of gas (164 Tm^3) are located in Russia and the Middle East (56,7 and 58,5 Tm^3 pt, respectively). The main centres of consumption of this source of energy, West Europe and North America, have much smaller reserves (7,7 Tm^3 and 6,4 Tm^3, respectively, or 4,7 % and 3,9 % of the world's reserves). Non-conventional gas reserves (hydrates) are presently not taken into account because of the unknown exploitation conditions and the price. With regard to the possibility of obtaining natural gas, West Europe has an advantage over North America because the supply is potentially possible through gas pipelines from the largest sites. The expected difference between the consumption and the production of gas in the European OECD countries will grow to about 200 billion m^3 by 2010 and to more than 400 billion m^3 by 2020, exceeding the production by more than two times within this group of countries. A similar forecast for the gas consumption in Europe is also given by Opservatiore Mediterraneen del Energie [8] which is expecting the difference between the demand and the production of natural gas in West Europe to grown to 500 billion m^3 around 2030. It will be possible to cover the difference between the demand and the production of gas by the import of natural gas through the gas pipelines from Russia and the Middle East via Turkey and Northern Africa (mostly Algeria). It is expected that gas imported from the Middle East will be the LNG. Because of the political instability in some exporting and transiting countries, the great length (4 000-6 000 km) and the complexity of the narast će 2010. godine na oko 200 milijardi m^3, a 2020. na više od 400 milijardi m^3 pa će time postati više nego dva puta veća od proizvodnje plina unutar te grupacije zemalja. Sličnu prognozu potrošnje plina za Europu daje i Opservatiore Mediterraneen del Energie [8] u kojoj se očekuje da će razlika potražnje i proizvodnje prirodnog plina u Zapadnoj Europi oko 2030. godine narasti na oko 500 milijardi m^3. Razlika između potražnje i proizvodnje plina moći će se namiriti uvozom prirodnog plina plinovodima iz Rusije i Bliskog istoka preko Turske i sjeverne Afrike (pretežno Alžira). Predviđa se uvoz plina iz Bliskog Istoka u ukapljenom stanju (LNG). Zbog političke nestabilnosti u nekim izvoznim i tranzitnim zemljama, velike dužine (4 000-6 000 km) i kompleksnosti trase plinovoda potencijalni je uvoz plina plinovodima iz nekih područja neizvjestan.

Važno je napomenuti da je u europskim zemljama ovisnost elektroenergetike o plinu sve izrazitija te se prema IEA [1] u razdoblju do 2020. godine očekuje linearni porast potrošnje plina u elektroenergetici sa stopom 5,5-6 % godišnje. Nasuprot tomu, u Sjevernoj Americi predviđa se da će porast potrošnje plina u elektroenergetici uglavnom prestati nakon 2010. godine, što znači da će trebati dalji porast konzuma pokriti utroškom drugih energenata (ugljen, nuklearna energija).

Zbog povećanja potrošnje plina u Europi trebat će proširiti kapacitete postojećih plinovoda i infrastukturnih objekata (kompresorske stanice, podzemni plinski spremnici), što je povezano sa znatnim troškovima. Prema procjeni Exxon-a [9], potrebna ulaganja u sustav transporta plina u Europu (računajući na transport iz Rusije) do 2020. godine bit će 300-350 milijardi USD. Prema istom izvoru uvjet su za tolika ulaganja potpuno tržišni uvjeti poslovanja (radi planiranog osiguranja povrata kapitala i dobiti), dakle odustajanje od bilo kakvog administrativnog ograničenja cijene plina. Gradnja sustava za dodatni transport plina (koja bi prema predviđanjima trajala najmanje 5 godina) vezana je ne samo uz osiguranje financiranja nego i uz rješavanje mnogobrojnih administrativnih pitanja i dozvola kako u zemlji izvoznici plina tako i u tranzitnim zemljama. Budućnost energetike u Europi, time i u Hrvatskoj, u znatnoj mjeri ovisi o pravodobnoj realizaciji tih investicijskih pothvata.

Gradnjom plinske elektrane, koja bi ulaskom u pogon oko 2010. godine mogla raditi 30-tak godina (do 2040.), investitori u Europi susreću se s rizikom raspoloživosti i neizvjesnosti cijene energenta. Razlog rizika, barem u srednjoročnom razdoblju, nije u iscrpljenju zaliha plina, nego u njegovoj cijeni, zbog povećane potražnje. Uzroci povećanja cijene prirodnog plina mogu biti manjkovi na tržištu zbog realne mogućnosti kašnjenja izgradnje plinovoda za pokriće povećane potrošnje plina u europskim

gas pipeline routes, the potential import of gas through the gas pipelines from some areas remains uncertain.

It is noteworthy that in European countries the dependence of electricity generation on gas is growing, and in the period until 2020, the IEA [1] expects a linear increase in the consumption of gas for electricity generation at a rate of 5,5-6 % per year. Contrariwise, it is predicted that the growth of the consumption of gas in electricity generation in North America will mostly subside after 2010, meaning that further growth of consumption will have to be compensated by the consumption of other sources of energy (coal, nuclear power).

Because of the growing consumption of gas in Europe it will be necessary to enlarge the capacity of the existing gas pipelines and infrastructural facilities (compressor stations, underground gas tanks) which is connected with considerable costs. According to Exxon's estimate [9], the required investment in the system of gas transport to Europe (notably from Russia) by 2020 will amount to 300-350 billion USD. According to the same source, the prerequisites to the investment on such a scale are full market-oriented operating conditions (to ensure the planned return on investment and profit), meaning a waiver of any administrative limitation of the price of gas. The construction of the system for the additional transport of gas (which according to estimates should last for at least 5 years) not only depends on providing the finances but also on resolving numerous administrative issues and obtaining permits both in the gas exporting country and in the transit countries. The future of the energy sector in Europe, including Croatia, depends to a considerable extent on the timely realisation of such investment ventures.

With the construction of a gas-fired electric power plant, which - commissioned around 2010 - could operate for some 30 years (until 2040) investors in Europe face the risk of uncertain availability and price of this source of energy. The reason for the risk, at least in the medium term, is not in the exhaustion of gas reserves but in the rising price of gas due to the high demand. The cause for the rising prices of natural gas may be shortages on the market due to real possibility of delays in the construction of gas pipelines meant to cover the increased gas consumption in European countries, the final costs of the construction of the gas pipeline, and taxes in transit states.

A sizeable increase in the price of the source of energy during the lifetime of a power plant can totally shatter the initial calculations of investment profitability.

The monopoly of gas pipeline suppliers could be partly compensated by importing liquefied natural gas (LNG), mostly from the Middle East. The position of Croatia regarding a LNG terminal is currently unclear. It would probably be useful to analyse how purposeful it would be to build an LNG terminal with the necessary infrastructure in Central and/or Northern Adriatic.

zemljama, konačni troškovi gradnje plinovoda te takse tranzitnih država.

Znatnije povećanje cijene energenta u tijeku životne dobi elektrane može potpuno poremetiti početne računice o rentabilnosti investicije.

Monopolistički položaj dobavljača plina plinovodima mogao bi se djelomično kompenzirati uvozom ukapljenog plina (LNG), pretežno iz zemalja Bliskog istoka. Položaj Hrvatske s obzirom na prihvat ukapljenog plina za sada je nejasan. Vjerojatno bi bilo korisno analizirati svrsishodnost izgradnje LNG terminala s pripadajućom infrastrukturom u srednjem i/ili sjevernom Jadranu.

U analizi pravaca razvoja energetike u Hrvatskoj [5] kao temeljni pravac dobave plina u Hrvatsku (oko 2/3 dobave), navodi se uvoz alžirskog plina plinovodom preko Italije (koji manjim dijelom uključuje i dobavu plina iz vlastitih bušotina INA-e na Jadranu). Pri ocjeni dugoročnije sigurnosti dobave prirodnog plina preko Italije treba biti vrlo oprezan. Italija je zemlja s najvećim deficitom u proizvodnji električne energije u Europi, pa će ona biti prisiljena ubrzano graditi vlastite elektrane (pritom će najvjerojatnije gradnja elektrana s prirodnim plinom kao energentom imati prioritet) i stoga će se kapacitetom postojećeg plinovoda morati koristiti za snabdijevanje vlastitih elektrana i ostale potrošnje.

Valja podsjetiti da je u cijeloj zapadnoj Europi, posebno u Njemačkoj, zbog pritiska javnosti (poticane od pokreta zelenih) obustavljena gradnja i djelomično obustavljen pogon nuklearnih elektrana, a obustavljena je i gradnja termoelektrana na ugljen, pa je kao jedina alternativa za sigurnu dobavu električne energije preostala gradnja termoelektrana na plinovito gorivo.

Jedan od načina smanjenja rizika za buduće iskorištavanje prirodnog plina sklapanje je dugoročnih ugovora s dobavljačem plina u kojima se mogu odrediti neki značajniji uvjeti dobave energenta. Prema procjeni IEA [10], gotovo 90 % isporuka plina za Europu do 2010. godine, kao i znatan dio predviđenih isporuka do 2020. godine, pokriveno je dugoročnim ugovorima. Trajanje dugoročnih ugovora proteže se do 25 godina.

O tome treba voditi računa u slučaju planiranja gradnje plinske elektrane u Hrvatskoj. Iz toga kratkog pregleda očigledno je da će pred eventualnim investitorom gradnje takve elektrane u Hrvatskoj stajati mnoge dileme zbog kojih će vjerojatno biti prisiljen tražiti da rizik gradnje i dugoročne rentabilnosti pogona, posebno u pogledu odnosa proizvodne i prodajne cijene električne energije, podijeli s državom. Osim toga, jedan od važnih preduvjeta za odluku o gradnji plinske elektrane trebalo bi biti sklapanje dugoročnog ugovora s pouzdanim dobavljačem prirodnog plina.

An analysis of developments in the energy sector in Croatia [5] shows that the basic route for gas supply (about 2/3 of Croatia's supply) includes the import of Algerian gas via gas pipeline through Italy (plus, to a lesser extent, Croatia's own supply from INA's wells in the Adriatic). In evaluating the long-term stability of natural gas supply through Italy one must be very cautious. Italy is the country with the biggest deficit in the generation of electric power in Europe, so it will be hard put to build its own electric power plants at a fast pace (probably giving priority to gas-fired plants) and to use the existing gas pipeline to supply its own plants and for the general consumption.

Throughout West Europe, particularly in Germany, the pressure of the public (encouraged by the environmentalist movement) resulted in the suspension of the construction and in a partial decommission of nuclear power plants, as well as in the suspension of the construction of coal-fired electric power plants, leaving the construction of gas-fired thermoelectric power plants as the only option for a stable supply of electricity.

One of the ways to reduce the risk in the future exploitation of natural gas is to conclude long-term agreements with gas suppliers to determine some of the important conditions for the supply of this source of energy. According to IEA estimates [10], almost 90 % of gas deliveries in Europe by 2010, and a significant portion of the deliveries envisaged by 2020, are covered by long-term agreements. The duration of long-term agreements extends up to 25 years.

This should be taken into account in case of considering the construction of a gas-fired plant in Croatia. It is apparent from this short overview that a possible investor in the construction of such a plant in Croatia will be facing many dilemmas which will probably make him seek to share with the state the risk of the construction and long-term profitability of the facility, particularly with regard to the relation between the production costs and the sales price of electricity. In addition, one of the important preconditions to the decision about the construction of a gas-fired power plant should be the conclusion of a long-term agreement with a reliable supplier of natural gas.

4 UTJECAJ ELEKTRANA NA OKOLIŠ

Neosporno je da gradnja i pogon svih tipova elektrana kao i drugih postrojenja elektroenergetskog sustava (transformatorske stanice, prijenos električne energije) nepovoljno utječe na prirodni okoliš. Ne postoji mogućnost da se osigura snabdijevanje potrošača električnom energijom uz potpuno isključenje tog utjecaja. Isto se može reći i za gotovo sve ljudske aktivnosti u modernom civiliziranom društvu (industrija, transport, građevinarstvo, poljoprivreda, turizam, telekomunikacije).

Budući da utjecaj na okoliš ovisi o vrsti elektrane, taj čimbenik treba uzeti u obzir pri planiranju i gradnji postrojenja. Kvalitativni utjecaj elektrana na okoliš poznat je duže vremena, ali je tek 1990-ih godina učinjen prvi ozbiljan napor da se taj utjecaj kvantificira. Kvantificiranje je definirano uvođenjem tzv. eksternih troškova (ili eksternalija) elektroenergetskih objekata i njima pripadajućih energetskih lanaca (lanac se proteže od iskopa i transporta rude, preko gradnje i pogona elektrane do skladištenja otpada).

Opsežnim epidemiološkim studijama u SAD-u ispitana je ovisnost oboljenja dišnih organa populacije u okolici termoenergetskih postrojenja o koncentraciji krutih čestica i aerosola (aerosoli nastaju u atmosferi kao posljedica emisija sumpornih i dušikovih oksida). Te su analize korištene kao temeljni oslonac za kvantificiranje štete u okolišu zbog pogona termoelektrana u okviru studija Europske zajednice ExternE 1995 i 1998 (s dodacima 2000. i 2001. godine) [11]. Utjecaj emisija termoelektrana na vegetaciju (zbog povećanja kiselosti tla) nije u tim studijama kvantificiran. Bitno je naglasiti da je funkcija ovisnosti štetnih posljedica i koncentracije linearna i da je pretpostavljena bez praga djelovanja.

Kvantificirani utjecaj neke elektrane na zdravlje stanovništva ovisi o prizemnoj koncentraciji krutih čestica i aerosola (koji nastaju kao posljedica emisija SO_2 i NO_x), gustoći populacije, zahvaćenom području i statističkoj vrijednosti ljudskog života (Value of Statistical Life-VSL) ili, ovisno o prihvaćenom načinu analize, o vrijednosti godine izgubljenog života (Value of Year of Life Lost v_{yoll}) [12], [13], [14].

Eksterni trošak neke elektrane nije jednoznačna veličina jer su bitni:

- lokalni i regionalni utjecaji koji ovise o lokaciji elektrane, površini zahvaćenog područja (bitno je, primjerice, uzima li se u razmatranje samo Hrvatska ili cijela Europa),
- meteorološki uvjeti za raspršenje emisija,
- računska vrijednost statističkog života u području zahvaćenom emisijama. Izračunani iznos VSL za

4 ENVIRONMENTAL IMPACT OF ELECTRIC POWER PLANTS

It is beyond any doubt that the construction and operation of all types of electric power plants and other facilities of the electric power sector (substations, power transmission) affects the natural environment. It is impossible to provide the supply of electricity to consumers with a complete exclusion of such an impact. The same may apply to almost any human activity in a modern civilised society (industry, transport, construction industry, agriculture, tourism, telecommunications).

The environmental impact depends on the type of the electric power plant, and this should be taken into account in planning and constructing the facility. That power plants affect the quality of the environment had been known for quite some time, but it was only in the 1990s that the first serious effort was made to quantify this impact. Quantifying the impact was defined by introducing the so-called external costs of electric power facilities and their energy chains (the chain stretches from excavation and transport of the source of energy, through the construction and operation of power plants, to the storage of waste).

Comprehensive epidemiological studies in the U.S.A. examined the interrelation between the incidence of respiratory tract diseases in the population living near thermoelectric facilities and the concentration of solid particulates and aerosols (aerosols are generated in the atmosphere as a result of the emissions of sulphur and nitrogen oxides). Such analyses were used as the basis for the quantification of the environmental damage caused by the operation of thermoelectric power plants, undertaken within the framework of the studies of the European Community ExternE in 1995 and 1998 (with additions in 2000 and 2001) [11]. The impact of the emissions from thermoelectric power plants on vegetation (due to the increased acidity of the soil) was not quantified in these studies. It is important to note that the function of interdependence between harmful effects and the concentration is linear and assumed without the effect threshold.

The quantified impact of a power plant on the health of the population depends on the concentration of solid particulates and aerosols (result of the emissions of SO_2 and NO_x) just above the ground, on the population density, the area affected and the Value of Statistical Life (VSL) or, depending on the analytical method accepted, on the Value of Year of Life Lost (v_{yoll}) [12], [13], [14].

The external cost of a power plant is not a single simple value, because its consideration includes:

- local and regional influences which depend on the location of the power plant, on the surface of the affected area (it is relevant e.g. whether it is just Croatia or the entire Europe that is taken into account), EU reda je 3 milijuna eura. Lako je zaključiti da je ta vrijednost ovisna o ekonomskoj snazi pojedine zemlje (dakle približno proporcionalna s njezinim BDP-om).

Mnogo je veća neizvjesnost u određivanju eksternog troška kada je u pitanju šteta u okolišu zbog emisije ugljičnog dioksida iz termoelektrana. Riječ je o globalnoj šteti, što znači da uzrok štete nije vezan uz lokaciju elektrana. U tom slučaju postoji ne samo nesigurnost u određivanju posljedica koncentracije ugljičnog dioksida u atmosferi na povišenje prosječne temperature, nego osobito u ocjeni šteta od klimatskih promjena.

Temeljni su razlozi za nesigurnost u ocjeni šteta zbog emisija CO_2 u atmosferu [11], [12], [13] i [14]:

- nedovoljna pouzdanost procjene veze između koncentracije CO_2 u atmosferi i povišenja prosječne temperature i klimatskih promjena,
- neravnomjeran raspored štete po područjima Zemlje. Neke države bit će više pogođene od drugih. Veća se šteta predviđa u nerazvijenim krajevima u južnim dijelovima Zemlje, jer su više ovisni o poljoprivredi, priobalnim aktivnostima te imaju slabiju medicinsku zaštitu. Manja se šteta očekuje u sjevernim razvijenim industrijskim zemljama. U nekim sjevernim zemalja (Rusija, Kanada) utjecaj globalnog zagrijavanja može biti čak pozitivan.

Na temelju analiza utjecaja štete na ukupni svjetski bruto društveni proizvod (BDP), zaključeno je da je utjecaj smanjenja dohotka nerazvijenih zemalja (zemalja najviše pogođenih globalnim zagrijavanjem) na globalni BDP malen. Predviđa se da će u budućnosti utjecaj nerazvijenih zemalja na svjetsku ekonomiju biti još manji, pa se ponekad javlja tendencija da se te štete podcjenjuju. Podcjenjivanjem šteta od globalnog zagrijavanja prebacuju se posljedice šteta s razvijenih zemalja na nerazvijene, što postaje osjetljivo etičko i političko pitanje.

U ekonomskoj praksi uobičajeno je sadašnju vrijednost budućih troškova dobiti diskontiranjem. U analizama šteta od globalnog zagrijavanja predložene su diskontne stope 0 % (tj. da vrijednost buduće štete, koja se proteže na razdoblje do 100 godina nakon emisije, ostaje ista kao da se ona dogodila danas), te 1 % i 3 %. Ako se želi umanjiti važnost i vrijednost budućih šteta treba računati s većom diskontnom stopom. Primjenom diskontne stope od 3 % predviđene buduće štete od globalnog zagrijavanja postaju zbog dugog razdoblja djelovanja gotovo zanemarive, čime bi i sve akcije za smanjenje današnjih emisija stakleničkih plinova postale bespredmetne. Kao kompromis, obično se za procjenu šteta od globalnog zagrijavanja

- meteorological conditions for the diffusion of emissions,
- mathematical value of the VSL in the area affected by emissions. The calculated value of the VSL for the EU is 3 million euros. It is easy to conclude that this value depends on the economic power of a country (i.e. it is approximately proportionate to a country's GDP).

There is a much greater uncertainty in determining the external cost when it comes to environmental damage caused by the emissions of carbon dioxide from electric power plants. This impact is global, which means that it is not limited to the site of the power plant. In this case it is not only difficult to estimate the impact of the concentration of carbon dioxide in the atmosphere on the increase in average temperature, but also to estimate the damage in terms of climatic changes.

The basic reasons for uncertainty in evaluating the damage caused by CO_2 emissions in the atmosphere [11], [12], [13] and [14] are:

- insufficient reliability of the interrelation between the concentration of the CO_2 in the atmosphere and the increase in average temperature and climatic changes,
- uneven distribution of damage over areas of Earth. Some states will be more affected than others. Greater damage is predicted in underdeveloped southern areas of Earth, because they depend more on agriculture, on coastal activities, and they have poor health care. Lesser damage is expected in developed northern industrial countries. In some northern countries (Russia, Canada) the effect of global warming may even be positive.

On the basis of the analyses of the impact on the general level of the global GNP, it has been concluded that the effect of the reduction in income for underdeveloped countries (which are affected by global warming the most) on the global GNP is minor. Estimates are that in the future the influence of underdeveloped countries on the world economy will be even smaller, and there is sometimes the tendency to underestimate such damage. Underestimating the damage from global warming shifts the consequences from developed to underdeveloped countries, which is becoming a volatile ethical and political issue.

In the economic practice it is normal to arrive at the present value of future expenses by discounting. In the analyses of the damage caused by global warming the proposed discount rates were 0 % (i.e. the value of the future damage, extending over the period of 100 years following the emissions, should remain the same as if it happened today), 1 % and 3 %. If we want to reduce the importance and the level of the future damage, a higher discount rate should be applied. By applying the discount rate of 3 % the predicted future damage from global warming becomes almost negligible because of the prolonged period under scrutiny, and it makes all the actions for the reduction of koristi diskontna stopa od 1 %. S etičkog stajališta najprimjerenije bi bilo računati s diskontnom stopom od 0 %.

Budući da je smanjenje emisija CO_2 vezano uz znatne troškove bilo za nove energetske izvore bilo za sustave za uskladištenje stakleničkih plinova, normalno je da, upravo koristeći se navedenim nesigurnostima u procjeni, pojedine interesne grupe iz područja energetike stimuliraju studije koje dokazuju malu opasnost od emisija ugljičnog dioksida.

Šteta od globalnog zagrijavanja obično se izražava po jedinici mase ispuštenog ugljičnog dioksida ili ispuštene mase ugljika, dakle kao EUR/tCO_2 ili EUR/tC. Do danas je izrađeno više desetaka studija u kojima procijenjene štete variraju čak unutar dvaju redova veličine. U okviru studije ExternE 97 procijenjeno je da će se šteta s 95 % vjerojatnosti naći u granicama 3,8 i 139 EUR/tCO_2 s najvjerojatnijim vrijednostima 18-46 EUR/tCO_2. Budući da termoelektrane na ugljen u prosjeku ispuštaju oko 0,9 kgCO_2/kWh, a termoelektrane na plin s kombiniranim ciklusom oko 0,4 kgCO_2/kWh, to bi cijena emisije u danim granicama za termoelektranu na ugljen značila eksterni trošak 1,6-4,1 eurocent/kWh, a za termoelektranu na plin 0,7-1,8 eurocent/kWh.

U mnogim analizama se umjesto proračuna štete u okolišu od emisija CO_2 kao ekvivalent cijeni ugljičnog dioksida računa cijena ekstrakcije i uskladištenja tog plina. U projektu tvrtke Vattenfal iz Švedske za gradnju probne termoelektrane u Brandenburgu računa se s cijenom ekstrakcije i odlaganja CO_2 u podzemne spremnike 20 EUR/t.

4.1 Obveze Hrvatske s obzirom na emisije CO_2

Stupanjem na snagu protokola iz Kyota Hrvatska bi bila obvezna u razdoblju od 2008. do 2012. smanjiti emisije CO_2 za 5 % u odnosu na 1990. godinu.

Obveza se lakše ispunjava ako su emisije 1990. godine bile veće. Stoga je za Hrvatsku (koja još nije ratificirala protokol iz Kyota) veoma bitno da joj se priznaju i tadašnje emisije iz termoelektrana u BiH i Srbiji koje su građene za potrebe Hrvatske.

Smanjenje emisije CO_2 nije samo ekološka kategorija nego i međunarodna obveza vezana uz plaćanje penala za njezino neispunjenje. To svakako treba uzeti u obzir pri planiranju gradnje budućih elektrana.

Prijašnje analize obavljene na Fakultetu elektrotehnike i računarstva (FER-u) pokazale su da se obveza Hrvatske na smanjenje emisija CO_2 uz istodobno osiguranje razvoja elektroenergetike u dugoročnijem razdoblju neće moći ispuniti bez gradnje nuklearnih elektrana.

present emissions of greenhouse gases pointless. As a compromise, normally the 1 % discount rate is applied in calculating the damage from global warming. From the ethical point of view the most appropriate thing to do would be to apply the 0 % discount rate.

Since the reduction in the emissions of CO_2 is connected with considerable expenses, be it for new sources of energy or for the systems to store greenhouse gases, it is individual interest groups in the energy sector, exploiting the above-mentioned uncertainty in estimates, that sponsor studies purporting the hazard of carbon dioxide emissions is small.

The damage from global warming is usually expressed per unit of mass of carbon dioxide released or the mass of carbon released, i.e. as EUR/tCO_2 or EUR/tC. To date, several dozen studies have been completed in which damage estimates vary by as much as two orders of magnitude. The study ExternE 97 estimates that the damage, with 95 % probability, will be between 3,8 and 139 EUR/tCO_2, the most probable values being 18-46 EUR/tCO_2. Considering that coal-fired power plants release about 0,9 kgCO_2/kWh on the average, and that gas-fired power plants with a combined cycle release about 0,4 kgCO_2/kWh, the cost of emissions within the limits established for a coal-fired power plant would mean an external cost of 1,6-4,1 eurocent/kWh, or 0,7-1,8 eurocent/kWh for a gas-fired power plant.

In many analyses the cost of extraction and storage of carbon dioxide is substituted for the calculation of environmental damage from CO_2 emissions, as an equivalent of the cost of carbon dioxide. In the project of the Swedish company Vattenfal for the construction of a trial thermoelectric power plant in Brandenburg, the cost of extraction and storage of CO_2 in underground storages is calculated at 20 EUR/t.

4.1 Obligations of Croatia with regard to CO_2 emissions

Entry into force of the Kyoto Protocol would mean the obligation for Croatia to reduce CO_2 emissions by 5 % between 2008 and 2012 compared with 1990.

The obligation is easier to meet if the emissions in 1990 were greater. It is, therefore, very important to Croatia (which still has not ratified the Kyoto Protocol) that it is acknowledged the emissions from thermoelectric power plants in Bosnia-Herzegovina and Serbia which were built to cover the demand of Croatia.

Reduction in CO_2 emissions is not only an environmental category but also an international commitment linked to the payment of penalties in case of default. This should by all means be taken into account in planning the construction of future power plants.

Previous analyses conducted at the Faculty of Electrical Engineering and Computing (FER) showed that it will not

4.2 Relativno vrednovanje elektrana sa stajališta utjecaja na okoliš

U studijama razvoja elektroenergetike i utjecaja elektrana na okoliš iz 2003. godine [12] i [13] kao karakteristični navode se eksterni troškovi elektrana u Njemačkoj. Ti su podaci navedeni u tablici 2. Dio eksternih troškova zbog emisija CO_2 temelji se na cijeni od 19 EUR/tCO_2 (taj je iznos dobiven procjenom najvjerojatnije vrijednosti unutar prihvaćenih granica 18-46 EUR/tCO_2).

be possible to fulfil the obligation of Croatia to reduce CO_2 emissions - in the light of the necessity to simultaneously ensure the development of the electric power sector in the longer term - without the construction of nuclear power plants.

4.2 Relative evaluation of electric power plants in terms of their environmental impact

In the 2003 studies [12] and [13] dealing with the development of electric power sector and the environmental impact of power plants, external costs of power plants in Germany were taken as characteristic. This data is given in Table 2 below. On account of CO_2 emissions, part of the external costs is based on 19 EUR/tCO_2 (this amount was arrived at by estimating the most probable value within the accepted limits of 18-46 EUR/tCO_2).

Tablica 2 - Eksterni troškovi elektrana u Njemačkoj / **Table 2** - External costs of power plants in Germany

Vrsta elektrane Type of power plant	Termoelektrana na ugljen Coal-fired thermoelectric power plant	Termoelektrana na plin u kombiniranom ciklusu Gas-fired thermoelectric power plant with combined cycle	Hidroelektrana Hydroelectric power plant	Vjetrena elektrana Wind power plant	Nuklearna elektrana Nuclear power plant
Eksterni trošak zbog emisija CO_2, External cost due to CO_2 emissions, eurocent/kWh	1,60	0,73	0,03	0,04	0,03
Eksterni trošak zbog emisija krutih čestica i aerosola, radioaktivnih tvari i buke, External costs due to emissions of solid particulates and aerosols, radioactive matter and noise, eurocent/kWh	0,95	0,39	0,08	0,12	0,17
Ukupni eksterni trošak, External costs in total, eurocent/kWh	2,55	1,12	0,11	0,16	0,20

Redoslijed povoljnosti energetskih tehnologija u odnosu prema okolišu u svim do danas izrađenim studijama ostao je nepromijenjen. Te tehnologije možemo prema štetnosti utjecaja na okoliš podijeliti na tri skupine:

- termoelektrane na ugljen,
- termoelektrane na plin,
- elektrane s obnovljivim izvorima energije i
- nuklearne elektrane.

Relativni odnos visine eksternih troškova (dakle šteta izazvana u okolišu po jedinici proizvedene energije) tih skupina elektrana je reda 100 % : 50 % : 10 %.

Takav je odnos ekološke povoljnosti elektrana, osim za nuklearne elektrane, prihvatila i šira javnost.

The order in terms of environmental acceptability of energy technologies in all the studies conducted to date has remained unchanged. In terms of their environmental impact these technologies can be divided into three groups:

- coal-fired power plants,
- gas-fired power plants,
- power plants utilising renewable sources of energy and
- nuclear power plants.

The relative relation of the level of external costs (i.e. damage to environment per unit of power generated) of the above groups is 100 % : 50 % : 10 %.

Such a relation of the environmental acceptability of power plants has also been widely accepted by the public, except for nuclear power plants.

5 STAJALIŠTE JAVNOSTI U POGLEDU GRADNJE ELEKTRANA

Mišljenje javnosti bitan je čimbenik u procesu odlučivanja o gradnji elektrana. To je mišljenje u najvećoj mjeri vezano uz normalni ili mogući utjecaj tih objekata na okoliš. Kod klasičnih elektrana na mišljenje javnosti djeluje utjecaj normalnog pogona (odnosno izvjesno predvidivih događanja) na okoliš, a kod nuklearnih elektrana posljedice hipotetičnog akcidenta.

Priprema gradnje elektrana mora uključiti u svoj program pripremu javnosti za takav pothvat kroz objektivno informiranje i educiranje najšire populacije. Samo se tako može izbjeći da javnost bude podvrgnuta manipulacijama protivnika gradnje elektrana, pojedinaca ili interesnih skupina. Javnosti bi trebalo obrazložiti činjenicu da su utjecaji elektrana na okoliš u svim fazama realizacije projekta predmet stručnih i znanstvenih analiza u kojima se provjerava ispunjenje svih postavljenih kriterija, te da u tom procesu nema mjesta za (nažalost česte) proizvoljne i nestručne tvrdnje. Bitno je argumentirano i transparentno obrazložiti zašto je (u medijima uvriježeno) netočno mišljenje da se termoelektrane i nuklearne elektrane mogu zamijeniti elektranama s obnovljivim izvorima.

Proces prihvaćanja gradnje elektrane od strane javnosti (pogotovo ako je riječ o "nepopularnom" objektu kao što je termoelektrana na ugljen ili nuklearna elektrana) može potrajati više godina. Zbog toga s tim aktivnostima treba započeti u najranijoj fazi pripreme za gradnju elektrane.

6 EKONOMSKI POKAZATELJI ELEKTRANA KANDIDATA ZA GRADNJU U HRVATSKOJ U IDUĆEM DESETLJEĆU

6.1 Očekivane proizvodne cijene električne energije u novim termoelektranama na kruta i plinovita goriva

Ekonomski pokazatelji elektrana kandidata za gradnju imaju bitan značaj za njihovu prihvatljivost kao proizvođača energije u elektroenergetskom sustavu. Posebno je interesantno razmotriti konkurentnost kandidata za gradnju u Hrvatskoj u kratkoročnom razdoblju, a to su termoelektrane na ugljen i na plin s kombiniranim ciklusom. Pritom je temeljni pokazatelj prosječna cijena proizvedene energije tijekom životne dobi elektrane uzevši u obzir očekivano povećanje cijene goriva i cijenu utjecaja na okoliš. Prikladan način proračuna za tu svrhu je poznata metoda

5 VIEWS OF THE PUBLIC CONCERNING THE CONSTRUCTION OF POWER PLANTS

Public opinion is an essential factor in the process of deciding on the construction of power plants. Public opinion is mostly related to the normal or possible environmental impact of such facilities. In traditional power plants the public opinion is influenced by the impact of the normal operation (i.e. of positively predictable developments) on the environment, whereas in nuclear power plants the effects of a hypothetical accident are considered.

The preparation for the construction of electric power plants must include the preparation of the public for such an undertaking by providing objective information and large-scale education of the population. It is the only way to avoid that the public be subject to manipulations from those who oppose the construction of power plants, individuals or interest groups. The public should be made aware that environmental impact of power plants is subject to professional and scientific analyses at all stages of project realisation, in which the conformity with all the set criteria is examined, and that in this process there is no place for (regrettably quite frequent) arbitrary and inexpert claims. It is important to explain with arguments and in a transparent manner why the view (popular with the media) that thermoelectric and nuclear power plants can be replaced by power plants utilising renewable sources of energy is false.

The process of public acceptance of the construction of power plants (particularly when it is an unpopular facility such as a coal-fired thermoelectric power plant or a nuclear power plant) may take several years. For that reason, the activities to achieve public acceptance should start at the earliest stage of preparation for the construction of a power plant.

6 ECONOMIC INDICATORS OF THE PLANTS ELIGIBLE FOR CONSTRUCTION IN CROATIA IN THE NEXT DECADE

6.1 Expected cost of power generated at new thermo-electric power plants burning solid fuel or gas

Economic indicators of eligible power plants are essential to their acceptability as electricity providers in the electric power system. It is particularly interesting to consider the competitiveness of the plants eligible in the short term: coal-fired plants and gas-fired plants with combined cycle. The basic indicator is the average cost of electricity during the lifetime of the plant, taking into account the expected increase in fuel price and the cost of environmental računa prosječne diskontirane cijene proizvedene energije na pragu elektrane, dobivene kao odnos diskontiranih troškova i diskontirane dobiti u životnoj dobi objekta (prema literaturi "levelized life time bus bar cost").

U Zavodu za visoki napon i energetiku FER-a razrađena je probabilistička metoda proračuna cijene proizvedene električne energije u termoelektrani na ugljen i onoj na plinovito gorivo u kombiniranom plinsko-parnom ciklusu. Primjena probabilističke analize potrebna je radi uvida u utjecaj nesigurnosti procjene ulaznih podataka proračuna na konačni rezultat i procjene rizika investitora u slučaju prihvaćanja jedne od ponuđenih opcija. U analizi je primijenjen računarski program STATS izvorno razvijen u Nacionalnom laboratoriju Argonne u SAD-u [15].

Upotrijebljeni izraz za proračun cijene energije ima oblik:

impact. An appropriate method of calculation in this case is the levelized lifetime bus-bar cost.

The Institute for High Voltage and Energy of FER has developed a probabilistic method for calculating the cost of the electricity generated at a coal-fired thermoelectric power plant and at a gas-fired power plant with a combined gas-steam cycle. The implementation of the probabilistic analysis is necessary to view the effect of the uncertainty of the estimated input data of the calculation on the final result and the risk evaluation by the investor in case one of the options is accepted. The analysis was run with the help of the STATS software originally developed by the Argonne National Laboratory in the U.S.A. [15].

The expression used to calculate the cost of energy is:

$$c_e = \frac{1}{8760 f_0}\left[\frac{I_n p}{(1-(1+p)^{-n}} \frac{\sum_{k=1}^{n}\frac{1}{(1+a)^k}}{\sum_{k=1}^{N}\frac{1}{(1+a)^k}} + c_{os}\right] + c_g \frac{\sum_{k=1}^{N}\frac{(1+p_g)^k}{(1+a)^k}}{\sum_{k=1}^{N}\frac{1}{(1+a)^k}} + c_{op} \qquad (1)$$

gdje je:

- c_e - cijena proizvedene električne energije (američki cent/kWh),
- p - kamatna stopa za povrat uloženog kapitala u gradnju elektrane,
- n - broj godina povrata kredita,
- N - broj godina rada elektrane,
- I_n - jedinična investicija na pragu elektrane (USD/kW) svedena na početak pogona (dakle s uključenim interkalarnim kamatama),
- c_{os} - stalni troškovi pogona i održavanja, bez goriva po jedinici snage na pragu elektrane (USD/kW),
- c_g - cijena goriva (američki cent/kWh) na pragu elektrane,
- c_{op} - promjenjivi troškovi pogona i održavanja po jedinici proizvedene energije na pragu elektrane (američki cent/kWh),
- f_0 - faktor iskorištavanja instalirane snage,
- a - diskontna stopa,
- p_g - stopa porasta cijene goriva.

- c_e - cost of electricity generated (U.S. cent/kWh),
- p - interest rate of the return on investment in the construction of the power plant,
- n - number of years of loan repayment,
- N - number of years of power plant operation,
- I_n - investment per unit at plant threshold (USD/kW) is reduced to the start of operation (i.e. with intercalary interest included),
- c_{os} - permanent operating and maintenance costs, excl. fuel per power unit at plant threshold (USD/kW),
- c_g - fuel cost (U.S. cent/kWh) at plant threshold,
- c_{op} - variable operating and maintenance costs per unit of electric power generated at plant threshold (U.S. cent/kWh),
- f_0 - capacity utilisation index,
- a - discount rate,
- p_g - fuel price growth rate.

Ulazni podaci za proračun dani su u tablici 3. Cijene su računane u američkim dolarima prema vrijednosti dolara krajem 2003. godine.

Input data for the calculation is shown in Table 3. Prices were calculated in USD at the exchange rates valid at the end of 2003.

Tablica 3 - Ulazni podaci za proračun cijene proizvedene električne energije termoelektrana
Table 3 - Input data for the calculation of the cost of electricity generated at thermoelectric power plants

Vrsta elektrane Type of facility	TE ugljen Coal-fired	TE plin (komb.ciklus) Gas-fired (comb.fired)
Specifična investicija (s interkalarnim kamatama), Specific investment (with intercalary interest), USD/kW	1 400-1 500-1 600 (Δ)	450-500-550 (Δ)
Stalni troškovi pogona i održavanja, Fixed operating and maintenance costs, USD/kWgod.	30-40 (-)	10-20 (-)
Cijena goriva, Fuel price, USD/GJ	1,8-1,9-2,0-2,1-2,2 (5T)	3,5-3,75-4,0-4,25-4,5 (5T)
Promjenjivi troškovi pogona i održavanja, Variable operating and maintenance costs U.S. cent/kWh	0,3-0,4 (-)	0,15-0,25 (-)
Radni vijek elektrane, god. Power plant lifetime, years	30	30
Razdoblje otplate kredita, god. Loan repayment period, years	15-20 (-)	12-15 (-)
Prosječne kamate na kredite, Average interest on loan, %	5,5-7,5 (-)	5,5-7,5 (-)
Diskontna stopa, Discount rate, %	5-8 (-)	5-8 (-)
Pretpostavljena prosječna stopa porasta cijene goriva u životnom vijeku elektrane, / Assumed average growth rate of fuel price during plant lifetime, %	1-2 (-)	4-6 (-)
Učinkovitost pretvorbe toplinske u električnu energiju, Efficiency of conversion of heat into electricity, %	38-42 (-)	54-62 (-)
Prosječno iskorištavanje instalirane snage, Average capacity utilisation, %	50-60-70 (Δ)	40-50-60 (Δ)
Eksterni trošak, External costs, U.S. cent/kWh	2-3 (-)	1-1,5 (-)

U tablici 3 su naznačene vjerojatne granične vrijednosti parametara (dobivene ne temelju analize postojećih podataka i prognoza) kao i očekivana raspodjela unutar graničnih vrijednosti. Raspodjela može biti jednolika (-), trokutasta (Δ), s najvjerojatnijom vrijednošću u sredini graničnih vrijednosti i u 5 točaka (5T). Program obavlja 2 000 proračuna izraza (1), sa slučajno odabranim varijablama unutar zadanih područja vodeći računa o raspodjelama unutar područja. Rezultati proračuna cijene električne energije grupiraju se unutar 50 intervala. Interval cijene unutar kojeg ulazi najveći broj slučajnih proračuna smatra se najvjerojatnijim u dobivenoj raspodjeli.

Sukladno očekivanjima, povišenje cijene plina prognozirano je s većom stopom nego povišenje cijene ugljena. Prognozirane stope porasta cijene plina odgovaraju udvostručenju cijene u intervalu 12-18 godina nakon ulaska elektrane u pogon. Takvo je očekivanje, prema postojećim analizama, najvjerojatnije optimistično, pa bi budući investitor morao računati barem s tolikim stopama povećanja cijena plina.

Table 3 shows probable parameter value limits (obtained on the basis of the analysis of available data and forecasts) as well as the expected distribution within the value limits. The distribution may be linear (-), triangular (Δ), with the most probable value in the middle between the value limits and at 5 points (5T). The program runs 2 000 calculations of the expression (1), with randomly selected variables within the ranges set, taking into account distributions within the range. The results of the calculation of the cost of electricity are grouped within 50 intervals. The price interval in which the largest number of random calculations fits is considered the most probable of the distributions obtained.

As expected, a higher increase in the price of gas is predicted than in the price of coal. The predicted growth rates of the gas price correspond with doubling the price within 12-18 years following the commission of the power plant. Such an expectation, according to the available analyses, is most probably an optimistic one, so a future investor should count with at least such growth rates of the gas price.

Očekivane granične vrijednosti ukupnih investicijskih troškova termoelektrana na ugljen i plin te drugi elementi troškova u kratkoročnom razdoblju sukladni su današnjem iskustvu. Prihvaćanje naprednijih tipova termoelektrana na ugljen (s internim rasplinjavanjem ugljena ili izgaranja u fluidiziranom sloju) neće, prema najavama, znatnije utjecati na povišenje specifičnih troškova u odnosu na sadašnje termoelektrane u kojima izgara ugljena prašina.

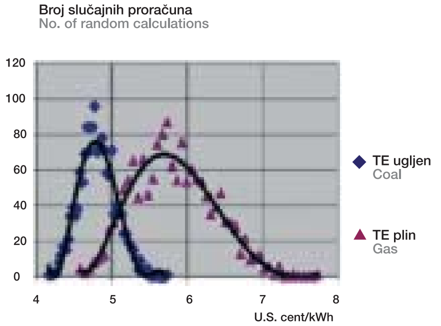
Zbog niže cijene goriva treba kod termoelektrane na ugljen računati s nešto većim prosječnim faktorom iskorištenja instalirane snage nego kod plinske elektrane.

Rezultati proračuna očekivane prosječne cijene proizvedene električne energije u životnoj dobi elektrane bez utjecaja eksternih troškova i s uključenim (interniziranim) eksternim troškovima dani su na slici 2.

The expected value limits for investment cost totals in coal-fired and in gas-fired thermoelectric power plants, and other costs in the short term, are consistent with the current experience. Accepting more advanced types of coal-fired thermoelectric power plants (FBC, IGCC) will not, according to announcements, effect any significant increase in the specific costs compared with the present thermoelectric plants burning coal dust.

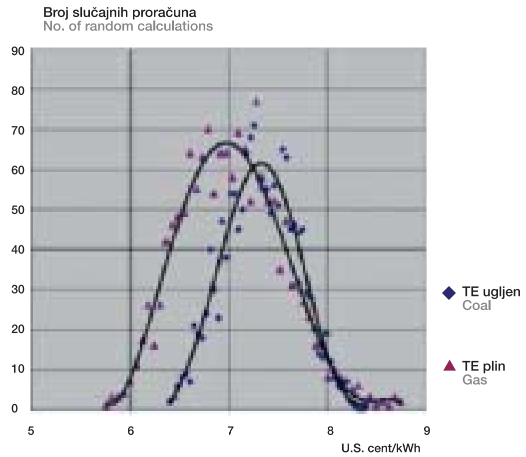
Due to the lower cost of the fuel, in coal-fired thermoelectric power plants one should count with somewhat higher average capacity utilisation index than in gas-fired power plants.

The results of the calculation of expected average cost of the electricity generated during power plant lifetime excl. external costs and incl. (internalised) external costs are shown in Figure 2.



Diskontna prosječna cijena električne energije bez eksternih troškova
Discounted average cost of electricity excl. external costs

Slika 2a
Figure 2a



Diskontna prosječna cijena električne energije s eksternim troškovima
Discounted average cost of electricity incl. external costs

Slika 2b
Figure 2b

Slika 2
Prosječna (u životnoj dobi) diskontirana cijena električne energije u termoelektrani na ugljen i termoelektrani na plin bez eksternih troškova i s njihovim uključenjem

Figure 2
Average (lifetime) discounted cost of electricity generated by a coal-fired thermoelectric power plant and a gas-fired thermoelectric power plant, without and with external costs

Rezultat pokazuje da bi uz zanemarivanje eksternih troškova i uz navedene ulazne podatke najvjerojatnija cijena električne energije proizvedene u životnoj dobi elektrane bila niža u termoelektrani na ugljen nego u termoelektrani na plin. Najvjerojatnije cijene bile bi oko 4,8 američki cent/kWh za termoelektranu na ugljen i oko 5,7 američki cent/kWh na termoelektranu na plin. Razlog je tomu prvenstveno u očekivanom poskupljenju prirodnog plina.

Kod vrednovanja elektrana treba uvažiti i moguće promjene faktora iskorištenja instalirane snage tijekom njihove životne dobi. Poskupljenje energenta pomiče elektranu u gornji dio dijagrama opterećenja i tako smanjuje njezino iskorištenje. S druge strane, porast konzuma ima suprotno djelovanje.

The result shows that notwithstanding the external costs, and with the mentioned input data, the most probable cost of electricity generated during the lifetime of a power plant would be lower for a coal-fired than for a gas-fired power plant. The most probable cost would be about 4.,8 U.S. cent/kWh for a coal-fired plant and about 5,7 U.S. cent/kWh for a gas-fired plant. The reason is primarily the expected increase in the price of natural gas.

In evaluating power plants one should also take into account possible changes in the capacity utilisation index during power plant lifetime. The increase in the price of the energy source moves the plant to the upper section of the burden graph, lowering its utilisation. On the other hand, consumption growth has the opposite effect.

Pri uporabi ugljena u elektroenergetici jedan je od bitnih problema u njegovu relativno nepovoljnom utjecaju na okoliš. Taj će se utjecaj, u dijelu koji se odnosi na utjecaj emisija krutih čestica i aerosola (dakle na lokalni i regionalni utjecaj elektrane koji izaziva najviše protivljenja stanovništva), moći smanjiti primjenom naprednijih tehnologija korištenja ugljena.

Uz pretpostavku da eksterni troškovi odražavaju štetu koju gradnja i pogon elektroenergetskih objekata izazivaju u okolišu, od interesa je usporediti ekonomičnost termoelektrana na kruto i plinovito gorivo uz uključenje (internizaciju) eksternih troškova. Srednje vrijednosti eksternih troškova termoelektrana na ugljen i plin preuzete su iz najnovije studije EU [12], prema tablici 2. Vjerojatno područje graničnih vrijednosti eksternih troškova na temelju navedenoga za termoelektranu na ugljen ocijenjeno je s 2-3 američki cent/kWh, a za termoelektranu na plin s 1-1,5 američki cent/kWh.

Rezultat proračuna cijene energije s uključenim eksternim troškovima ilustriran je slikom 2b.

Iz slike proizlazi da uključenje (internizacija) eksternih troškova u proračun cijene proizvedene električne energije daje određenu prednost termoelektrani na plinovito gorivo (unatoč specificiranom povećanju cijene plina). Najvjerojatnija visina diskontiranih cijena električne energije s uključenjem eksternih troškova iznosi oko 7 američki cent/kWh za termoelektranu na plinovito gorivo i oko 7,3 američki cent/kWh za termoelektranu na ugljen.

Ako bi se utjecaj termoelektrana na okoliš ograničio samo na emisije CO_2 te prihvatila srednja cijena 20 EUR/tCO_2, dobila bi se razlika cijene emisija termoelektrane na ugljen i termoelektrane na plin od približno 0,9 eurocent/kWh. Dodajući taj iznos cijeni električne energije proizvedene u termoelektrani na ugljen na slici 2a, cijene proizvedene električne energije u jednoj i drugoj elektrani postaju gotovo izjednačene.

One of the major problems in using coal to generate electricity is coal's relatively negative impact on the environment. This impact, in the segment related to the emissions of solid particulates and aerosols (i.e. to the local and regional impacts of the plant which provoke the most opposition from the population), will be possible to reduce by implementing advanced technologies in utilising coal.

Under the assumption that the external costs reflect the damage caused by the construction and by the operation of power facilities to the environment, it is interesting to compare the cost effectiveness of thermoelectric power plants burning solid fuel and of those burning gas, with the external costs included (internalised). Mean values of the external costs of coal-fired and gas-fired thermoelectric power plants were taken over from the most recent EU study [12], according to Table 2. The probable value limits for the external costs were thus 2-3 U.S. cent/kWh for a coal-fired plant and 1-1,5 U.S. U.S. cent/kWh for a gas-fired plant.

The result of the calculation of the cost of electricity with the external costs included is shown in Figure 2b.

It follows from the figure that the inclusion of the external costs in the calculation of the cost of electricity generated gives some advantage to a gas-fired plant (in spite of the specified increase in the price of gas). The most probable level of discounted electricity with the external costs included is about 7 U.S. cent/kWh for a gas-fired plant, and about 7,3 U.S. cent/kWh for a coal-fired plant.

Limiting the environmental impact of thermoelectric power plants just to CO_2 emissions and accepting the mean cost of 20 EUR/tCO_2, one would arrive at the difference in the cost of emissions between coal-fired and gas-fired thermoelectric power plants of approximately 0,9 eurocent/kWh. If you add this amount to the cost of electric power generated by a coal-fired plant according to Figure 2a, the level of the cost of electricity generated by either type of plant is almost the same.

7 ULOGA UVOZA ELEKTRIČNE ENERGIJE U HRVATSKU ZA PODMIRENJE BUDUĆIH POTREBA

Izravni uvoz električne energije može biti jedan od načina za snabdijevanje potrošača u Hrvatskoj. Međutim, isključivo i dugoročno oslanjanje na uvoz električne energije vrlo je nepouzdano, jer ovisi o nepredvidivim raspoloživim viškovima električne energije na inozemnom tržištu, mogućnostima prijenosa te energije, kao i o potražnji električne energije od drugih zemalja. Elektrane se u osnovi ne grade radi izvoza električne energije nego za podmirenje vlastite potrošnje. Navedena tvrdnja može se potkrijepiti činjenicom da se potencijalni viškovi kapaciteta za proizvodnju električne energije u svim europskim zemljama već nekoliko godina neprekidno smanjuju. Povremeni viškovi električne energije na tržištu mogu nastati zbog prekomjerne gradnje elektrana u nekim zemljama zbog neostvarena predviđenog porasta domaćega konzuma. Valja naglasiti da se zbog dužeg razdoblja podinvestiranja u proizvodnju i prijenos električne energije u Europi, uz istodobno povećanje konzuma i izlaženje iz pogona zastarjelih elektrana, u bliskoj budućnosti može smanjiti ponuda viškova električne energije na koje Hrvatska može računati. Odnos potražnje i ponude električne energije na tržištu utječe na cijenu uvezene energije. Ako je alternativa uvozu redukcija potrošnje tada cijena može biti vrlo visoka.

8 KRATKOROČNI I SREDNJOROČNI PROGRAM GRADNJE ELEKTRANA U HRVATSKOJ

Na osnovi navedenih potreba gradnje elektrana u Hrvatskoj analizirat će se moguće opcije gradnje u dva razdoblja:

- u kratkoročnom razdoblju (do 2010. godine) i
- u srednjoročnom razdoblju (do 2020. godine).

8.1 Kratkoročni program gradnje elektrana

Na temelju iznesenih činjenica može se zaključiti sljedeće:

Radi podmirenja potrebnih količina električne energije za potrošače u Hrvatskoj u idućem kratkoročnom razdoblju (do 2010. godine) trebalo bi osigurati mogućnost proizvodnje oko dodatnih 3 TWh te zamijeniti dio postojećih elektrana koje će zastarjeti.

7 ROLE OF THE IMPORT OF ELECTRICITY IN MEETING THE FUTURE DEMAND IN CROATIA

Direct import of electricity can be one of the ways to supply consumers in Croatia. However, exclusive and long-term reliance on the import of electricity is very unreliable, because it depends on unpredictable electricity surpluses on the international market, on the facilities for the transmission of such electricity, and on the demand for electricity by other countries. Electric power plants are basically not built to export electricity but to meet one's own needs. This claim can be supported by the fact that potential excessive capacities for generating electricity in all the European countries have been relentlessly diminishing for several years now. Occasional electricity surpluses may be found on the market owing to excessive construction in some countries resulting from the failure to achieve the predicted growth of domestic consumption. It should be noted that due to longer periods of sub-investment in the generation and transmission of electricity in Europe, with a simultaneous increase in consumption and decommission of obsolete plants, the offer of electricity surpluses to which Croatia could count may go down in the near future. The relation between the demand and supply for electricity on the market affects the cost of imported electricity. If the alternative to the import is reduction in consumption, the cost can rise very high.

8 SHORT-TERM AND MEDIUM-TERM PROGRAMS OF POWER PLANT CONSTRUCTION IN CROATIA

On the basis of defined needs for the construction of power plants in Croatia, possible options will be analysed for two periods:

- short-term period (by 2010) and
- medium-term period (by 2020).

8.1 Electric power plant construction in the short-term

On the basis of the facts presented the following may be concluded:

To provide the necessary electricity for consumers in Croatia in the next short-term period (by 2010), the potential to additionally generate about 3 TWh should be ensured, and some of the existing power plants (which will become obsolete) replaced.

The consumption could be covered by the construction of a gas-fired and/or coal-fired thermoelectric power plants.

Potrebe konzuma mogle bi se zadovoljiti gradnjom termoelektrana na plinovito gorivo i/ili kruto gorivo.

Kao eventualni dopunski izvori energije mogu doći u obzir i elektrane koje iskorištavaju obnovljive izvore energije. Gradnjom elektrana na obnovljive izvore praktično se ne može smanjiti potrebna snaga termoelektrana, nego samo njihova proizvodnja.

Prednosti i mane raspoloživih opcija u kratkoročnom planu gradnje elektrana u Hrvatskoj

Termoelektrana na ugljen (snage reda 500 MW*).*
Prednosti i mane te opcije mogu se na temelju prethodnih izlaganja sažeti prema sljedećem:

Prednosti:
- stabilna raspoloživost i stabilna cijena energenta,
- dugoročna perspektiva korištenja ugljena u elektroenergetici u svijetu,
- povoljna cijena proizvedene električne energije ako se u cijenu ne uključe eksterni troškovi.

Mane:
- visoki investicijski troškovi u usporedbi s elektranom na plinovito gorivo,
- nepovoljan utjecaj na okoliš (visoki eksterni troškovi),
- nepovoljno prihvaćanje u javnosti,
- veoma otežano ispunjenje obveze o smanjenju emisija CO_2,
- privremena administrativna zabrana pripremnih radova,
- ograničenje lokacija na priobalje.

Lokalni utjecaj na okoliš (zbog emisija krutih čestica i aerosola) termoelektrane na ugljen može se poboljšati prihvaćanjem novih tehnologija gradnje tih elektrana, koje su već razvijene za primjenu (termoelektrane s izgaranjem u fluidiziranom sloju ili s rasplinjavanjem ugljena).

Termoelektrana na prirodni plin s kombiniranim plinsko-parnim ciklusom (snage do 300 MW*)*

Prednosti:
- niska investicijska ulaganja u gradnju elektrane,
- povoljna cijena proizvedene električne energije uz današnju cijenu prirodnog plina,
- povoljniji utjecaj na okoliš (niži eksterni troškovi) u usporedbi s termoelektranom na ugljen,
- povoljno prihvaćanje u javnosti.

Mane:
- potencijalni problemi s osiguranjem dobave energenta, a time i s pouzdanim snabdijevanjem potrošača električne energije,

Possible supplementary sources of electricity could also be power plants utilising renewable resources. The construction of power plants utilising renewable resources cannot reduce the required capacity of thermoelectric power plants, it can only reduce their required output.

Advantages and disadvantages of available options in the short-term program of power plant construction in Croatia

Coal-fired thermoelectric power plants (output capacity 500 MW).
Advantages and disadvantages of this option can be summarised as follows:

Advantages:
- stable availability and stable price of energy source,
- long-term global prospects of using coal to generate electricity,
- favourable cost of electricity generated when external costs are excluded.

Disadvantages:
- high investment costs compared with gas-fired plants,
- negative environmental impact (high external costs),
- negative reception in the public,
- very difficult to meet the commitment to reduce CO_2 emissions,
- temporary administrative ban on preparatory works,
- possible sites limited to coastal area.

Local environmental impact (because of the emissions of solid particulates and aerosols) of a coal-fired plant can be improved by implementing new technologies in the construction of plants, which have already been developed and ready for use (FBC or IGCC).

Natural gas-fired thermoelectric power plant with combined gas-steam cycle (output capacity up to 300 MW*)*

Advantages:
- low cost of investment in the construction of the plant,
- favourable cost of electricity generated at today's price of natural gas,
- less negative environmental impact (lower external costs) compared with coal-fired plant,
- positive acceptance in the public.

Disadvantages:
- possible problems with providing fuel and, consequently, reliability of supplying consumers with electricity,
- probable considerable increase in the price of natural gas during the lifetime of the plant and consequent higher risk of the investor with regard to the profitability of investment,
- more difficult to meet the commitment to reduce CO_2 emissions.

- vjerojatnost osjetnijeg povećanja cijene prirodnog plina u vremenu pogona elektrane i povećani rizik investitora s obzirom na rentabilnost investicije,
- otežano ispunjenje obveze prema smanjenju emisija CO_2.

Budući da s jedne strane svaka od dviju navedenih opcija gradnje termoelektrana u Hrvatskoj u idućem kratkoročnom razdoblju ima prednosti i mane, a s druge strane, načelo diversifikacije izvora energije zahtijeva osiguranje energije iz više izvora, prijeko je potrebno hitno započeti s paralelnim akcijama za gradnju jedne i druge vrste elektrana. Paralelna je priprema za gradnju svrsishodna jer zbog navedenih teškoća jedna od opcija može otpasti tijekom priprema.Valja podsjetiti da vremensko razdoblje od početka priprema za gradnju do stavljanja elektrane u pogon u našim uvjetima traje 5-10 godina, pa bi pripreme za gradnju elektrana s namjeravanim ulaskom u pogon do 2010. godine trebalo početi odmah. Posebno dugotrajne mogu biti početne faze priprema, osobito ako se ne radi o zamjenskom objektu na poznatoj lokaciji.

Visoka vanjska zaduženost i vanjskotrgovinski deficit Hrvatske biti će jedan od glavnih čimbenika pri odluci o realizaciji gradnje elektrana. Prednost će imati opcije s nižim investicijskim troškovima ili dobivene u specijalnim okolnostima (podmirenje duga), te uz prepuštanje gradnje stranim investitorima.

Jedino pravodobnim početkom priprema za gradnju elektrana može se ostvariti potrebno povećanje proizvodnje električne energije u Hrvatskoj u idućm desetljeću i spriječiti ekonomski kolaps koji bi bio uzrokovan dugotrajnijom redukcijom (ionako skromne) potrošnje električne energije.

8.2 Srednjoročno razdoblje (od 2010. do 2020. godine) gradnje elektrana u Hrvatskoj

Iz razmatranja u uvodnom dijelu ove rasprave slijedi da bi uz uvjet izgradnje predviđenih elektrana do 2010. godine u srednjoročnom razdoblju trebalo uz pretpostavku minimalnog porasta konzuma osigurati izgradnju daljnjih elektrana, s ukupnom instaliranom snagom 1 000-1 500 MW.

Od realnih opcija energetskih tehnologija koje stoje na raspolaganju za gradnju postrojenja za pouzdanu proizvodnju električne energije situacija nije bitno različita od one koja je prije bila razmatrana u okviru kratkoročnog plana gradnje elektrana.

Očekuje se da će u tom razdoblju tehnologija ugljenih elektrana biti unaprijeđena uvođenjem u komercijalnu primjenu poboljšanih načina izgaranja ugljena (izgaranje u fluidiziranom sloju, interno rasplinjavanje ugljena) čime će se smanjiti emisije sumpornih i

Considering, one the one hand, that either of the above options has its advantages and disadvantages and, on the other hand, that the principle of diversification of the sources of energy requires electricity to be provided from diverse sources, it is absolutely necessary to urgently begin with simultaneous activities for the construction of both types of electric power plants. Parallel preparation for the construction is meaningful because the difficulties presented could disqualify one of the options during the preparations. Note that the period from the beginning of preparations for the construction to commissioning the plant usually takes 5-10 years in Croatia, so the preparation for the construction of electric power plants to be commissioned by 2010 should begin right away. The initial phases of preparation can take particularly long time, especially if the plant to be constructed is not a replacement facility at a familiar location.

High foreign debt and foreign trade deficit of Croatia will be major factors in deciding on the construction of electric power plants. Options with lower investment costs or those set up under special circumstances (debt repayment) will be favoured, as well as those involving foreign investors.

It is only through a timely start of the preparations for the construction of electric power plants that the necessary increase in the generation of electricity in Croatia in the next decade can be achieved and the economic collapse prevented that would be caused by a possible prolonged reduction in the (already modest) consumption of electricity.

8.2 Electric power plant construction in Croatia in the medium term (from 2010 to 2020)

From the introduction to this section of the discussion follows that, provided the envisaged plants are built by 2010, in the medium term, and with the assumption of a minimum increase in general consumption, it would be necessary to ensure the construction of further electric power plants with a total output capacity of 1 000-1 500 MW.

With regard to real options of power technologies for building facilities to reliably generate electricity, the situation is not much different than the one discussed earlier in respect of the short-term plan for the construction of electric power plants.

It is expected that in this period the technology of coal-fired power plants will be improved by implementing improved coal combustion methods (FBC, IGCC), which will reduce emissions of sulphur and nitrogen oxides and solid particulates (whereas the emissions of CO_2 will remain approximately the same) compared with the present combustion of coal dust. Procedures for the separation and storage of CO_2 [16] are being prepared. By minimizing local and regional damage to the environment new technologies in the construction of coal-fired plants dušikovih oksida te krutih čestica (dok emisije CO_2 ostaju približno iste) u odnosu na današnje izgaranje ugljene prašine. U razvoju su i postupci za separaciju i uskladištenje CO_2 [16]. Ublažavanjem lokalnih i regionalnih šteta u okolišu nove bi tehnologije gradnje termoelektrana na ugljen mogle pridonijeti olakšanju uvjeta za lociranje tih elektrana.

U pogledu uvjeta korištenja plina u elektroenergetici se ne mogu očekivati poboljšanja već naprotiv zaoštravanja. Položaj dobavljača plina s obzirom na potrošače (posebno u uvjetima znatne potražnje i nepostojanja alternative) može postati u znatnoj mjeri monopolistički. U posebno nepovoljnom stanju mogu se naći mali potrošači poput Hrvatske. Problem se može donekle ublažiti osiguranjem dugoročnih ugovora za sigurnu dobavu plina pod određenim uvjetima i/ili gradnjom LNG terminala koji omogućuju diversifikaciju dobave. U nekim se razmatranjima IEA navodi i mogućnost da dobavljači plina preuzmu vlasništvo nad plinskim elektranama, jer na taj način sigurna dobava plina postaje i njihov interes.

Zbog navedenih razloga u svim se analizama buduće proizvodnje električne energije u europskim zemljama povećava važnost diversifikacije izvora dobave energenata i vrste energenata. Računa se i na povrat šire primjene ugljena u elektroenergetici, a u nekim zemljama i na revitalizaciju nuklearnih programa. U SAD-u su takve ideje već službeno prihvaćene, što potvrđuje prognoza o prestanku porasta potrošnje plina u elektroenergetici i početak gradnje nove generacije nuklearnih elektrana već u ovom desetljeću.

Hrvatska kao energetski deficitarna zemlja i zbog toga upućena na uvoz energenata, mora svoje programe razvoja energetike uskladiti s planovima drugih europskih zemalja (posebno onih koje ju okružuju). To se posebno odnosi na diversifikaciju u korištenju putova dobave i vrste energenata te na osiguranje snabdijevanja svojih potrošača vlastitom proizvodnjom električne energije (uz istodobnu brigu o mogućnosti prijenosa električne energije u susjedna područja radi izmjene energije i boljeg osiguranja snabdijevanja potrošača u iznimnim uvjetima).

U srednjoročnom planu za Hrvatsku, osim daljnjega korištenja plina, ugljena te obnovljivih izvora energije, ostaje otvorena i opcija korištenja nuklearne energije.

Današnji pogledi na status i perspektive nuklearne energetike u Hrvatskoj su razmotreni u sljedećem izlaganju.

could contribute to easing up the conditions for the location of such plants.

In terms of utilising gas to generate electricity no improvements can be expected; on the contrary, the situation can be expected to deteriorate. The position of the gas supplier with regard to consumers (particularly with soaring demand and no alternative) can become pretty much a monopolistic one. Small customers such as Croatia can find themselves in a precarious position. The problem can be mitigated to an extent by securing long-term contracts for a stable gas supply under certain conditions and/or the construction of LNG terminal to enable diversified supply. Some IEA considerations note the possibility that gas suppliers could acquire ownership of gas-fired power plants to make sure a stable supply of gas is in their interest, too.

For the reasons mentioned all the analyses of the future generation of electricity in European countries increasingly underline the importance of diversification of fuel supply sources and fuel types. The return of a large-scale utilisation of coal in electricity generation is also something to count with, and in some countries also with the reinstatement of nuclear programs. In the U.S.A. such ideas have already been officially accepted, which is supported by the forecast that the increase in the consumption of gas in power generation will stop and that the construction of a new generation of nuclear power plants will begin already in this decade.

Croatia as a country lacking energy resources, and therefore hard put to import sources of energy, must harmonise its programs for the development of the energy sector with the plans of other European countries (particularly the one in its surroundings). This particularly applies to the diversification of the supply routes and fuels and to securing the supply to all domestic consumers of the power generated in the country (simultaneously providing for the possibilities to transmit electricity to neighbouring areas for the sake of power exchange and to be able to better supply consumers in contingencies).

The medium-term program for Croatia, in addition to further utilisation of gas, coal and renewable sources of energy, also contains the option of the utilisation nuclear power.

Today's views of the status and prospects of nuclear power in Croatia are discussed below.

9 PERSPEKTIVA PRIMJENE NUKLEARNE ENERGIJE U HRVATSKOJ

Nuklearne elektrane dosegnule su razinu pouzdanog i ekonomičnog izvora električne energije. To potvrđuje i rad NE Krško u protekle 23 godine pogona.

Prema najnovijem izvještaju IAEA u svijetu je u pogonu 441 nuklearna elektrana s ukupnom instaliranom snagom 358 661 MW, koje su u 2002. godini proizvele 2 574 TWh električne energije, što pokazuje da je njihovo prosječno iskorištenje instalirane snage 7 176 h/god. (odnosno da je prosječan faktor opterećenja oko 82 %). Najviše je izgrađenih nuklearnih elektrana u SAD-u (109), zatim u Francuskoj (59), Japanu (54), Vel. Britaniji (31), Rusiji (30), Njemačkoj (19), Južnoj Koreji (18), Kanadi (14). Krajem 2002. godine u svijetu u bile u izgradnji 32 nuklearne elektrane (najviše u Indiji (7) i Kini (4)).

Među europskim zemljama upravo je odlučena gradnja nuklearne elektrane u Finskoj (koja već ima 4 nuklearne elektrane u pogonu). Osim u Finskoj zbog opisanih teškoća s osiguranjem dobave i poskupljenjem plina kao i problemima zbog emisija stakleničkih plinova iz termoelektrana, u još nekim europskim zemljama (posebno Francuskoj) obnavlja se razmatranje o budućnosti nuklearnih energetskih programa. Zemlje Dalekog istoka (osobito Kina, Južna Koreja i Indija) nastavljaju s intenzivnom gradnjom nuklearnih elektrana. U SAD-u se očekuje narudžba novih nuklearnih elektrana još u ovom desetljeću.

Nakon zastoja gradnje nuklearnih elektrana (nakon kvara na elektrani Otok tri milje u 1979. godini, a ponajprije zbog poskupljenja gradnje elektrana zbog odugovlačenja s licenciranjem već gotovih postrojenja) dolazi u razdoblju od 1980. do 1990. god. do razradbe projekata nuklearnih elektrana s poboljšanim sigurnosnim sustavima (treća generacija). Nekoliko izgrađenih nuklearnih elektrana (prvenstveno u Japanu) ili u fazi gradnje (Finska) ulazi u tu kategoriju.

Radi dugoročnog rješenja sigurnog pogona ne samo elektrana nego i njihova gorivnog ciklusa (uključivši i sigurnost od terorističkih napada) te sigurnosti od nekontroliranog širenja nuklearnih materijala pokrenuta je u SAD-u inicijativa za razradbu nove generacije nuklearnih elektrana (četvrta generacija) [18] i [19]. Tipovi elektrana koje ulaze u tu kategoriju dijelom su neispitani pa će njihova razradba i komercijalna primjena zahtijevati duže vremensko razdoblje (vjerojatno do 2030. godine ili još duže). Od nuklearnih elektrana četvrte generacije očekuje se:

9 NUCLEAR POWER PROSPECTS IN CROATIA

Nuclear power plants have reached the level of reliable and economic source of electricity. This has been supported by the operation of the Krško nuclear power plant in the past 23 years of operation.

According to the most recent IAEA report there are 441 nuclear power plants throughout the world, with a total output capacity of 358 661 MW, which in 2002 generated 2 574 TWh electric power, showing the average capacity utilisation of 7 176 h/year (i.e. average utilisation index of about 82 %). The largest number of nuclear power plants have been built in the U.S.A. (109), France (59), Japan (54), United Kingdom (31), Russia (30), Germany (19), South Korea(18), Canada (14). At the end of 2002, 32 nuclear power plants were under construction world-wide (the largest number of them in India (7) and China (4)).

In Europe, it has already been decided to build a nuclear power plant in Finland (where there already are 4 nuclear power plants in operation). In addition to Finland, due to the described difficulties concerning the secure supply and the increase in the price of gas, as well as with the emissions of greenhouse gases from thermoelectric power plants, some other European countries (particularly France) are again considering nuclear power programs for the future. Far East countries (particularly China, South Korea and India) are continuing to busily build nuclear power plants. In the United States, new orders for the construction of nuclear power plants are expected already in this decade.

After a hold-up in the construction of nuclear power plants (following the accident at the Three Mile Island in 1979, but primarily because the construction of power plants became more expensive on account of delayed licensing of already finished facilities) there followed a development of nuclear power plant designs with improved security systems between 1980 and 1990 (third generation). Several nuclear power plants already built (primarily in Japan) or under construction (Finland) fall into this category.

For the sake of a long-term solution to the safe operation of both power plants and their fuel cycle (including safety from terrorist attacks) and the prevention of uncontrolled proliferation of nuclear materials, an initiative has been launched in the U.S.A. to develop a new generation of nuclear power plants (fourth generation) [18] and [19]. Types of power plants falling into this category are partly untested and their development and commercial implementation will take a longer time (probably until 2030 or even longer). Fourth generation nuclear power plants are expected to feature:

- niža specifična investicija,
- učinkovitije korištenje nuklearnoga goriva,
- smanjena količina visokoradioaktivnog otpada,
- veći stupanj sigurnosti od velikih kvarova izazvanih unutarnjim ili vanjskim uzrocima,
- manja mogućnost proliferacije nuklearnih materijala.

Vjerojatno je da su za razradbu projekata nuklearnih elektrana četvrte generacije bitniji razlozi otežavanje terorističkih napada i proliferacije nuklearnih materijala, učinkovitije korištenje nuklearnoga goriva i proizvodnja vodika, nego znatnije poboljšanje sigurnosti pogona same elektrane i znatnije sniženje investicije. Takav se zaključak nameće zbog toga što je normalna pogonska sigurnost nuklearnih elektrana današnjih izvedbi na iznimno visokoj razini (rizik stanovništva od nuklearnih akcidenata neusporedivo je manji od rizika iz drugih uzroka). Analizama je dokazana vjerojatnost topljenja jezgre današnjih energetskih reaktora reda 10^{-5}, a vjerojatnost većeg ispuštanja radioaktivnosti u okoliš u granicama 10^{-7}-10^{-6} događaja po godini pogona reaktora. Upitno je bi li se racionalnim razlozima mogao pravdati zahtjev za još višim stupnjem sigurnosti pogona nuklearnih elektrana.

Do stjecanja pogonskog iskustva i komercijalne primjene nuklearnih elektrana četvrte generacije, (kao i fuzijskih elektrana koje se također razvijaju) za primjenu će biti raspoložive sadašnje elektrane druge i treće generacije kod kojih su pogonska sigurnost i pouzdanost veoma dobri.

U uvjetima današnjeg stupnja razvoja nuklearne energetike i prognoziranih potreba za njezinom budućom primjenom potrebno je i definirati optimalnu strategiju Hrvatske u pogledu nuklearne opcije.

9.1 Prednosti i mane nuklearne opcije

Prema sadašnjim su saznanjima prednosti i mane nuklearne opcije:

Prednosti:
- konkurentna cijena proizvedene električne energije,
- očekivana stabilnost raspoloživosti i cijene energenta,
- dugoročna perspektiva korištenja nuklearne energije u elektroenergetici u svijetu,
- povoljan utjecaj elektrane na okoliš (niski eksterni troškovi),
- ispunjenje obveze o smanjenju emisija CO_2.

Mane:
- visoka specifična investicija i dugo vrijeme gradnje (4-5 godina),

- lower specific investment,
- more efficient utilisation of nuclear fuel,
- reduced quantity of highly radioactive waste,
- higher level of safety from major internally or externally caused failures,
- less possibility for the proliferation of nuclear materials.

In the development of projects for nuclear power plants of the 4th generation the prevailing reasons are more probably to make terrorist attacks and the proliferation of nuclear materials more difficult, to more efficiently utilise nuclear fuel and to produce hydrogen, than to make a noticeable improvement in the safety of the operation of the plant and to lower the cost of investment. The normal operating safety of nuclear power plants today is extremely high (the risk to the population from nuclear accidents is vastly lower compared with other causes). Analyses have proved the probability of core meltdown in today's reactors of 10^{-5}, and the probability of a significant release of radioactivity in the environment between 10^{7} to 10^{-6} occurrences per year of reactor operation. It is questionable whether a demand for an even higher level of safety in the operation of nuclear power plants could reasonably be justified.

Until there is operational experience and commercial implementation of nuclear power plants of the 4th generation (and the fusion power plants that are also being developed), what is at disposal for the present use are the 2nd and 3rd generation power plants with very good operational safety and reliability.

At the present stage of development of nuclear power utilisation and the predicted need for its future use it is necessary to define the optimum strategy for Croatia concerning the nuclear option.

9.1 Advantages and disadvantages of the nuclear option

According to the current state of knowledge, the advantages and disadvantages of the nuclear option are:

Advantages:
- competitive cost of generated power,
- expected stable availability and price of the source of energy,
- long-term prospects for the use of nuclear power in generating electricity world-wide,
- low negative impact of the power plant on the environment (low external costs),
- meeting the requirement concerning the reduction in CO_2.emmissions

Disadvantages:
- high specific investment cost and long construction time (4-5 years),
- incompletely accepted manner of the definite disposal of deradiated nuclear fuel and highly radioactive waste*,

- nepotpuno prihvaćen način konačnog odlaganja odzračenoga nuklearnoga goriva i visokoradioaktivnog otpada*,
- nepovoljno prihvaćanje u javnosti (bez obzira na povoljan utjecaj nuklearne elektrane na okoliš),
- privremena administrativna zabrana pripremnih radova (kao i za termoelektranu na ugljen).

**Primjedba:*

Rješenjem problema dugoročnog uskladištenja visokoradioaktivnog otpada u SAD-u i Finskoj (a vjerojatno i u Rusiji) otpala je primjedba da je taj problem nerješiv.

Nadalje, dugoročna aktivnost visokoradioaktivnog otpada smanjit će se primjenom postrojenja za odjeljivanje i transmutaciju dugovjekih aktinida (P&T). Postrojenja tog tipa koja se danas intenzivno unapređuju u nizu razvijenih zemalja, smanjit će dugoročnu opasnost od radioaktivnog otpada za oko 100 puta.

Na odluku Hrvatske o gradnji nuklearne elektrane svakako će utjecati i stav razvijenijih europskih zemalja. Prema današnjim saznanjima, pozitivniji odnos prema nuklearnoj energetici u Europi se može, zbog očekivanih teškoća s dobavom i cijenom prirodnog plina, poboljšanim izvedbama nuklearnih elektrana i već odlučenom revitalizacijom nuklearne energetike u SAD-u, s priličnom vjerojatnošću očekivati početkom naznačenoga srednjoročnog razdoblja (tj. nakon 2010. godine).

Odluka o prihvatljivosti nuklearne opcije u Hrvatskoj, kada se za nju ispune ostali uvjeti, ovisiti će o ekonomskoj konkurentnosti te opcije s obzirom na druge mogućnosti (termoelektrana na ugljen i na plin uz očekivano poskupljenje energenata). **Pritom se kao temeljna pitanja za konkurentnost opcija postavlja visina investicije nuklearne elektrane i očekivana promjena cijene plina tijekom životne dobi postrojenja.** Pri analizi granično konkurentne investicije nuklearne elektrane treba poštovati realno procijenjene granice nesigurnosti ulaznih parametara o kojima ovisi rezultat analize.

9.2 Potencijalna konkurentnost nuklearne elektrane

Ekonomska konkurentnost nuklearnih elektrana u prvom redu ovisi o njihovim ukupnim investicijskim troškovima. To su troškovi gradnje (overnight costs) i interkalarne kamate. Interkalarne kamate ovisne o kamatnoj stopi i trajanju gradnje elektrane i veoma opterećuju investiciju ako se iz nekog razloga vrijeme gradnje produži.

Zbog uvida u potencijalnu ekonomsku konkurentnost nuklearne elektrane, na FER-u [20] je izrađena analiza granične investicije nuklearne elektrane. Granična investicija definirana je kao najviša vrijednost ukupne specifične investicije uz koju

- begative reception in the public (irrespectively of the less negative impact of nuclear power plants on the environment),
- temporary administrative ban on preparatory work (same as for coal-fired thermoelectric power plants).

**Note:*

The fact that the problem of the long-term storage of highly radioactive waste has been solved in the U.S.A and Finland (and probably in Russia) eliminates the objection that this problem is insoluble.

Furthermore, the long-term activity of radioactive waste will be reduced with the implementation of facilities for the separation and transmutation of long-life actinides (P&T). Such facilities which are presently being intensively improved in a number of industrial countries will reduce the long-term risk from radioactive waste by about 100 times.

Croatia's decision about the construction of a nuclear power plant will surely be influenced by the views of developed European countries as well. From what we know, a more positive attitude towards nuclear power in Europe can be expected with great probability at the beginning of the medium-term period in question (i.e. after 2010) owing to the expected problems in and the prices of natural gas, the improved design of nuclear power plants and the already decided revitalisation of nuclear power utilities in the U.S.A.

The decision on the acceptability of the nuclear option in Croatia, once other requirements have been met, will depend on the economic competitiveness of this compared with other options (coal-fired and gas-fired thermoelectric power plants with the expected increase in the price of energy sources). **The basic questions concerning competitive advantages of the options are the cost of investment of nuclear power plant and the increase in the price of gas during the plant lifetime.** In the analysis of the competitive investment cost for a nuclear power plant, the realistically estimated variation of input parameters on which the result of the analysis depends needs to be respected.

9.2 Potential competitive edge of nuclear power plant

The economic competitive edge of nuclear power plants depends primarily on their total investment costs. These costs include the cost of construction (overnight costs) and intercalary interest. Intercalary interest depend on the interest rate and the duration of construction, burdening the investment cost very much if for some reason or other the duration of the construction is prolonged.

In order to determine the potential economic competitiveness of a nuclear power plant, FER [20] conducted an analysis of the competitive investment cost for a nuclear power plant. The competitive cost is defined as the highest value of the total specific investment at which the average (levelized) cost of electricity generated at the power plant prosječna (nivelirana) cijena električne energije proizvedene u nuklearnoj elektrani tijekom njezine životne dobi postaje konkurentnom cijeni energije proizvedene u elektrani na ugljen i elektrani na plin s kombiniranim ciklusom.

Račun je izveden za slučaj bez eksternih troškova elektrana i uz te troškove.

Ulazni podaci za nuklearnu elektranu navedeni su u tablici 4. Pretpostavljeni podaci za nuklearnu elektranu relativno su konzervativni. Kamatne stope na uložena sredstva i radni vijek uzeti za nuklearnu elektranu isti su kao za termoelektrane na fosilna goriva (iako je takva pretpostavka, zbog potencijalno dužega radnog vijeka, nepovoljna za nuklearnu elektranu). Nadalje, pretpostavljeni stalni troškovi pogona i održavanja za nuklearnu elektranu (100-120 USD/kWgod.) nešto su viši od vrijednosti publiciranih za postojeće nuklearne elektrane u pogonu.

during its lifetime becomes competitive to the cost of electricity generated by a coal-fired plant or a gas-fired plant with combined cycle.

The calculation was conducted with and without the external costs of power plants.

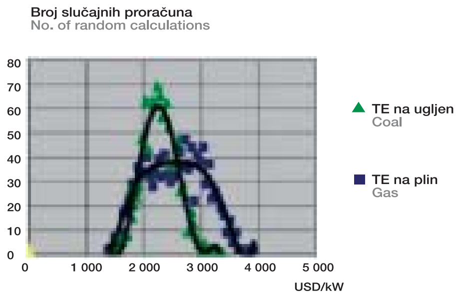
The input data for a nuclear power plant are given in Table 4. The assumed data for a nuclear power plant are relatively conservative. The interest rate on the funds invested and the lifetime of nuclear power plant are the same as for thermoelectric power plants burning fossil fuels (although under such an assumption the nuclear power plant is at a disadvantage because of the potentially longer lifetime). Furthermore, the assumed fixed operating and maintenance costs for the nuclear power plant (100-120 USD/kWyear) are slightly higher than the values published for the existing operating nuclear power plants.

Tablica 4 - Ulazni podaci za procjenu ekonomičnosti nuklearne elektrane uz današnju vrijednost dolara
Table 4 - Input data for estimating cost effectiveness of a nuclear power plant at the present value of U.S. dollar

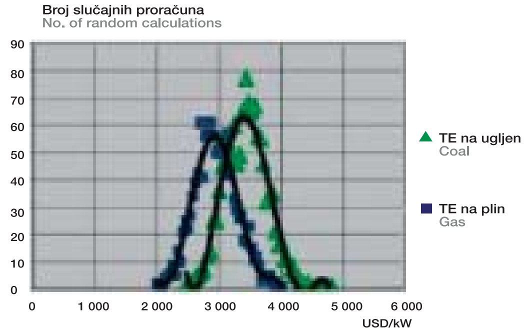
	Nuklearna elektrana Nuclear power plant
Stalni troškovi pogona i održavanja, Fixed operating and maintenance costs, USD/kWgod.	100-120 (-)
Cijena goriva, Fuel price, USD/GJ	0,45-0,5-0,55 (Δ)
Promjenjivi troškovi pogona i održavanja, Variable operating and maintenance costs, U.S. cent/kWh	0,3-0,4 (-)
Radni vijek elektrane, god. Plant lifetime, year	30
Razdoblje otplate kredita, god. Loan repayment period, year	15-20 (-)
Prosječne kamate na kredite, Average interest on loan, %	5,5-7,5 (-)
Diskontna stopa, Discount rate, %	5-8 (-)
Pretpostavljena prosječna stopa porasta cijene goriva u životnom vijeku elektrane, Assumed average growth rate of fuel price during plant lifetime, %	1-2 (-)
Učinkovitost pretvorbe toplinske u električnu energiju, Efficiency of the conversion of heat into electricity, %	32-34 (-)
Prosječno iskorištenje instalirane snage, Average utilisation of capacity, %	75-85 (-)
Eksterni trošak , External cost, U.S. cent/kWh	0,2-0,7 (-)

Rezultati analize prikazani su na slici 3.

The results of the analysis are shown in Figure 3.



Slika 3a
Figure 3a



Slika 3b
Figure 3b

Slika 3
Granična investicija nuklearne elektrane u usporedbi s termoelektranama na plin i ugljen, bez eksternih troškova i s njihovim uključenjem

Figure 3
Competitive investment cost for a nuclear power plant compared with gas-fired or coal-fired thermoelectric power plants, without and with the external costs

Na temelju slike 3 možemo zaključiti čak ako zanemarimo eksterne troškove, odnosno utjecaj šteta na okolišu, da je najvjerojatniji iznos granične specifične investicije nuklearne elektrane oko 2 200 USD/kW ako ju uspoređujemo s termoelektranom na ugljen i oko 2 700 USD/kW ako ju uspoređujemo s termoelektranom na plin.

Ako se u račun uključe i eksterni troškovi elektrana (koji su za elektrane s fosilnim gorivima, a osobito za termoelektrane na ugljen, znatno veći nego za nuklearne elektrane), najvjerojatnija visina granične investicije nuklearne elektrane u usporedbi s termoelektranom na plinovito gorivo raste na oko 2 900 USD/kW, a u usporedbi s termoelektranom na ugljen čak na oko 3 400 USD/kW.

Prema najnovijoj studiji IEA (izrađenoj na Sveučilištu u Chicagu 2004.) [21] o ekonomičnosti budućih nuklearnih elektrana generacija 3, odnosno 3+ (ABWR i AP1000), procjene specifičnih troškova bez interkalarnih kamata tih elektrana (overnight costs) **kreću se u granicama 1 400-1 600 USD/kW.** Inter-kalarne kamate za trajanje gradnje 5 godina i kamatnu stopu 7 % povećavaju specifičnu investiciju za 20-25 %, što daje očekivane **ukupne specifične troškove u granicama 1 700-2 000 USD/kW.**

Usporedbom s rezultatima proračuna graničnih investicija nuklearnih **elektrana realno je očekivati ekonomsku konkurentnost nuklearnih elektrana s termoelektranama na kruta i plinovita goriva, čak i uz zanemarene eksterne troškove pogona tih elektrana.**

Jedan od glavnih poticaja eventualnim investitorima gradnje nuklearne elektrane očekivana je dobit tijekom životne dobi objekta u odnosu na druge opcije. Glavni konkurent nuklearnoj elektrani danas je termoelektrana na plinovito gorivo u kombiniranom ciklusu. Radi kvantificiranja pokazatelja dobiti, s

It may be concluded on the basis of Figure 3 that even if we leave external costs i.e. harmful environmental impact aside, the most probable level of specific competitive investment cost for the nuclear power plant is about 2 200 USD/kW compared with the coal-fired thermoelectric power plant, or about 2 700 USD/kW compared with the gas-fired thermoelectric power plant.

If the calculation includes external costs of power plants (which are considerably greater for thermoelectric power plants burning fossil fuels, particularly coal, than for nuclear power plants), the most probable level of competitive investment cost for the nuclear power plant compared with the gas-fired plant rises to about 2 900 USD/kW, or to as much as 3 400 USD/kW compared with the coal-fired plant.

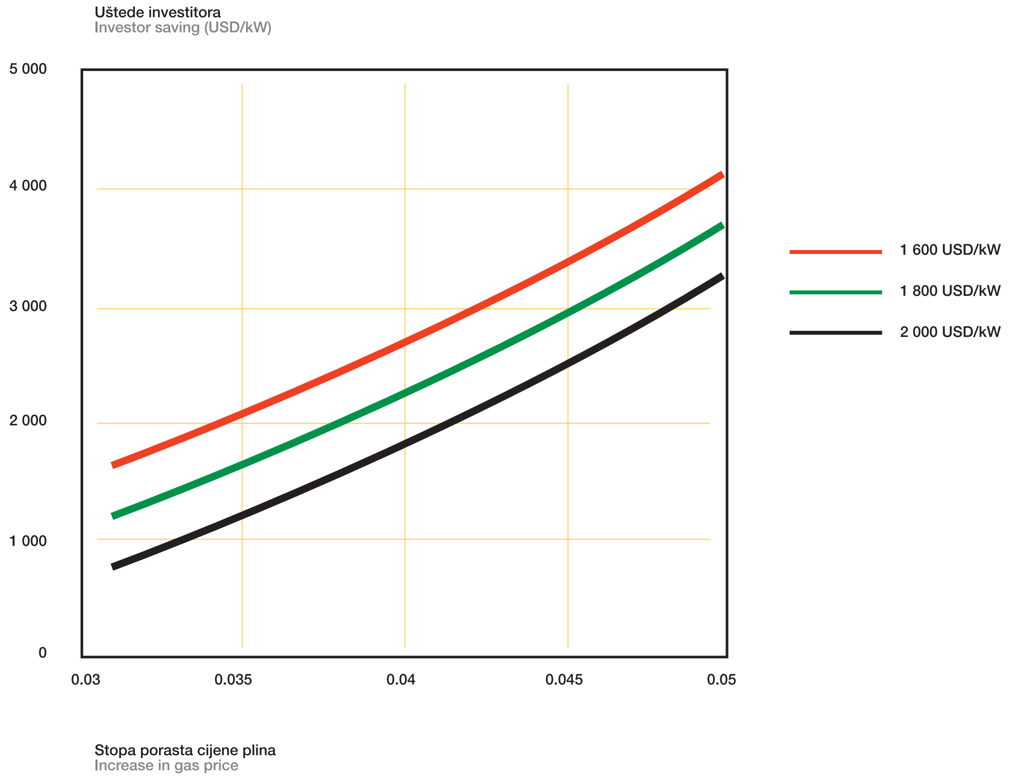
According to the most recent IEA study (prepared at the University of Chicago in 2004) [21] concerning the cost effectiveness of the future nuclear power plants of the 3rd generation, i.e. 3+ (ABWR and AP1000), the estimates of specific costs excl. the intercalary interest (overnight costs) **are between 1 400 and 1 600 USD/kW.** The intercalary interest for a 5 year construction period and a 7% interest rate boost the specific investment cost by 20-25 %, which results in the **total specific costs between 1 700 and 2 000 USD/kW.**

Comparing the results of the calculation of competitive investment cost for a nuclear power plant, **it is realistic to expect that nuclear power plants will be competitive compared with coal-fired and gas-fired thermoelectric power plants, even if the external costs are left aside.**

One of the main incentives to potential investors in the construction of nuclear power plants is the expected profit during plant lifetime compared with the other two options. The main competitor to the nuclear power plant today is the gas-fired thermoelectric power plant with combined cycle. To quantify the profit indicator, the expression (1) and the method described above were used to calculate pomoću izraza (1) i prethodno opisane metode izrađen je proračun razlike najvjerojatnije srednje nivelirane cijene proizvedene električne energije u životnoj dobi plinske i nuklearne elektrane, pomnožene s očekivano proizvedenom količinom električne energije. Ta se veličina može označiti kao pokazatelj razlike dobiti odnosno ušteda investitora. Temeljni utjecaji na konkurentnost opcija su visina investicije nuklearne elektrane i očekivana stopa porasta cijene plina. Račun je izrađen za ukupne investicije NE od 1 600, 1 800 i 2 000 USD/kW i prosječne godišnje stope porasta cijene prirodnog plina 3-5 %. Rezultat proračuna prikazuje slika 4.

the difference between the most probable mean levelized cost of electricity generated during the lifetime of the gas-fired thermoelectric power plant and of the nuclear power plant, multiplied by the expected quantity of the electricity generated. This value may be taken as an indicator of the difference in the profit i.e. saving for the investor. What affects the competitiveness of the options is the level of investment cost of the nuclear power plant and the expected increase in the price of gas. The calculation was made for the total investment cost of the nuclear power plant of 1 600, 1 800 and 2 000 USD/kW and the average annual increase in the price of natural gas of 3-5 %. The result of the calculation is shown in Figure 4.

Slika 4
Pokazatelji rentabilnosti gradnje nuklearne elektrane
Figure 4
Indicators of profitability of the construction of a nuclear power plant



Račun pokazuje da kod, primjerice, najviše očekivane investicije NE od 2 000 USD/kW ušteda tijekom životne dobi postaje veća od početne investicije, ako je prosječna stopa porasta cijene plina veća od 4 %.

Uz uključenje (internizaciju) eksternih troškova ušteda postaje još znatno veća. Prema tablici 2 razlika je eksternih troškova između plinske i nuklearne elektrane oko 0,9 eurocent/kWh, što u životnoj dobi elektrane daje dodatnu uštedu od oko 1 900 EUR/kW.

The calculation shows, for example, that with the highest expected investment cost of the nuclear power plant amounting to 2 000 USD/kW the saving during plant lifetime exceeds the initial investment cost if the average increase in the price of gas exceeds 4 %.

When the external costs are included, the saving is considerably greater. Table 2 shows that the difference between the external costs of the gas-fired power plant and the nuclear power plant is about 0,9 eurocent/kWh, which adds a saving of about 1 900 EUR/kW for the plant lifetime.

9.3 Potrebne aktivnosti za realizaciju nuklearne opcije u srednjoročnom razdoblju

Na temelju izvršene analize za Hrvatsku kao i svjetskih predviđanja o primjeni nuklearne energije u idućim desetljećima moglo bi se zaključiti da je nuklearna opcija i za Hrvatsku potencijalno povoljna, te da treba ostati bitan element u planiranju razvoja elektroenergetskog sustava u srednjoročnom razdoblju. Takav zaključak potkrepljuje i pozitivno iskustvo s pogonom NE Krško.

Da bi se obavile što djelotvornije pripreme za nuklearnu opciju treba osigurati pripremu hrvatskih inženjerskih kadrova i ponovno pokrenuti interes industrije za nuklearnu tehnologiju radi omogućivanja dobave dijela nuklearne opreme u Hrvatsku kao i izvođenje građevinskih, montažnih radova i remonta nuklearnog postrojenja od domaćih poduzeća (što je uspješno realizirano već 1970-ih godina prilikom gradnje NE Krško).

Interes dijela hrvatske industrije i projektanata (osobito poduzeća Končar, Đ. Đaković, TPK, Jedinstvo, Hidroelektra, Elektroprojekt) za nuklearnu tehnologiju u 1960-im i 1970-im godinama bio je vrlo izražen.

Realno je očekivati da će pripreme gradnje nuklearne elektrane u Hrvatskoj (na temelju iskustva drugih zemalja, a posebno u našim uvjetima) biti kompleksne i dugotrajne. Kako bi se osigurao početak gradnje nuklearne elektrane za oko 10 godina i dovršetak gradnje za oko 15 godina, s pripremama treba početi što prije. Radi usporedbe, valja podsjetiti da je priprema gradnje i gradnja NE Krško trajala oko 12 godina (1970.-1982.), u uvjetima kada je unaprijed bila nominirana lokacija i kada je postojala opća potpora za što brži dovršetak gradnje elektrane. Iz toga slijedi da rok ulaska nuklearne elektrane u pogon do godine 2020. ne bi bilo lako ostvariti.

10 ZAKLJUČAK O OPCIJAMA IZBORA ELEKTRANA ZA POKRIĆE TEMELJNOG OPTEREĆENJA HRVATSKOG ELEKTROENERGETSKOG SUSTAVA U SREDNJOROČNOM RAZDOBLJU

Za pokriće minimalno potrebne gradnje elektrana (2 000-2 200 MW) u srednjoročnom razdoblju (2010.-2020. god.) na raspolaganju stoje, osim ograničenih mogućnosti gradnje elektrana s obnovljivim izvorima energije, opcije gradnje elektrana na plin, ugljen i nuklearno gorivo. **Uzevši u obzir opisane prednosti i ograničenja navedenih opcija, potrebu**

9.3 Activities necessary for the realisation of the nuclear option in the medium term

On the basis of the analysis conducted for Croatia and the global predictions concerning the utilisation of nuclear power in the decades to come, it could be concluded that the nuclear option, too, is potentially favourable for Croatia, and that it should remain an important element in planning the development of the electric power system in the medium term. Such a conclusion is also supported by the positive experience with the Krško nuclear power plant.

In order to conduct as effective as possible preparations for the nuclear option, Croatian engineering staff should be prepared and the interest of the industry in the nuclear technology rekindled to enable the supply of some of the nuclear equipment and the performance of construction works, assembly and maintenance of nuclear facilities by domestic companies (this was successfully done already in the 1970's when the Krško nuclear power plant was built).

There was a very live interest on the part of Croatian industry and designers (in particular the companies Končar, Đ. Đaković, TPK, Jedinstvo, Hidroelektra, Elektroprojekt) for the nuclear technology in the 1960's and the 1970's.

It is realistic to expect that the preparation for the construction of a nuclear power plant in Croatia (on the basis of the experience of other countries, and even more so under the specific conditions in Croatia) will be complex and of long duration. In order to secure the beginning of the construction of a nuclear power plant in about 10 years and the completion of the construction in about 15 years, the preparations should begin as soon as possible. For the sake of comparison, the preparation and construction of the Krško nuclear power plant took about 12 years (1970-1982), with the site nominated in advance and with the consensus on the soonest possible completion of the construction. It follows that the deadline for the nuclear power plant to be commissioned by 2020 would not be easily honoured.

10 CONCLUSION ABOUT THE POWER PLANT OPTIONS TO COVER THE BASIC LOAD IN CROATIA'S POWER SYSTEM IN THE MEDIUM TERM

The options for the construction of the minimum required capacity (2 000-2 200 MW) in the medium term (2010-2020) include, beside the limited potentials for the construction of power plants utilising renewable sources of energy, the construction of gas-fired and coal-fired thermoelectric power plants, and nuclear power plants. **Considering the presented advantages and disadvantages of the options described, the need for the diversification in the generation of electricity, and the long time (up**

diversifikacije u proizvodnji električne energije kao i dugo vrijeme (čak i do 10 godina) pripremnih radova potrebno je promptno početi sa studijskim radovima za njihovu realizaciju (osobito u svezi izbora lokacija, istražnih radova na lokacijama, ekonomskih studija o perspektivnim cijenama energenata i visini investicijskih ulaganja, studija utjecaja na okoliš, nadogradnje regulative, mogućih opcija vlasništva i financiranja gradnje elektrana, veličine agregata, priključaka na mrežu i stabilnosti elektroenergetskog sustava). Radi što boljeg iskorištenja vremena za pripremne radove trebalo bi njima obuhvatiti **svaku od navedenih opcija elektrana.** To će dopustiti vjerodostojan uvid u njihova ograničenja, ekonomičnost i mogućnost pravodobne realizacije za pokriće očekivanoga konzuma u Hrvatskoj. **Tek nakon dovršenja najbitnijih pripremnih radova moguće je utemeljeno odrediti izbor i redoslijed gradnje elektrana u srednjoročnom razdoblju.**

to 10 years) for preparatory works, it is necessary to promptly begin to prepare the necessary studies (particularly regarding the choice of locations, on-site inspection works, economic studies into the prospective pricing of energy sources and the level of investment costs, environmental impact studies, amendment of legislation, possible plant ownership and construction financing options, output capacity, network connections and stability of the power system). To best use the time for preparatory works, the works should be simultaneously performed for **each of the above-mentioned power plant options**. This will allow a trustworthy insight into their limitations, cost effectiveness and the possibility of their timely realisation to meet the expected demand in Croatia. **It is only after the essential preparatory works have been completed that it is possible to make a founded choice and determine the order of the construction of electric power plants in the medium term.**

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Uredništvo primilo rukopis:
2005-11-08

Prihvaćeno:
2005-11-22

Manuscript received on:
2005-11-08

Accepted on:
2005-11-22