ANALIZA POJAVE NEGATIVNE CIJENE NA SPOT TRŽIŠTU ELEKTRIČNE ENERGIJE EUROPSKE BURZE ENERGIJE EEX

ANALYSIS OF THE OCCURRENCE OF THE NEGATIVE PRICE ON THE EUROPEAN ENERGY EXCHANGE (EEX) ELECTRICITY SPOT MARKET

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Europska burza energije EEX postala je, uz Nord Pool u nordijskim zemljama, najznačajnija burza energije u kontinentalnoj Europi. Cijene i prilike s EEX-a nerijetko predstavljaju referencu u trgovanju električnom energijom na lokalnim ili regionalnim tržištima europskih zemalja. U radu je prikazana i razmatrana pojava negativne cijene na spot tržištu električne energije na EEX-u krajem prosinca 2008. godine. Negativna cijena, kada je predviđena i dopuštena u strukturi tržišnog modela na burzi energije, odražava situaciju na tržištu u kojoj je ponuda značajno nadmašila potražnju. Premda je postizanje negativne cijene na tržištu električne energije više izuzetak nego pravilo, zanimljivo je sagledati što uzrokuje takve neobične pojave. Od njenog uvođenja na EEX-u negativna tržišna cijena postignuta je tek nekoliko puta, uglavnom u pojedinačnim satima noću kada je potrošnja električne energije u pravilu smanjena. Situacija analizirana u ovom radu zanimljiva je jer je negativna cijena postignuta u razdoblju od nekoliko uzastopnih sati te zbog postignutih iznosa negativne cijene, pa su u radu razmotreni mogući uzroci koji su do toga doveli. Budući da su europski elektroenergetski sustavi dobro povezani, provedena je analiza i u radu je predočeno kako su se razmatrana zbivanja u zapadnoj i središnjoj Europi odrazila na tokove električne energije u hrvatskom elektroenergetskom sustavu i njegovom okruženju.

The EEX (European Energy Exchange) has become, along with Nord Pool in Nordic countries, the most significant energy exchange in continental Europe. EEX's prices and possibilities often represent a reference in the electricity trade on the local or regional markets of European countries. The work also shows and deliberates on the occurrence of negative prices on the EEX electricity spot market at the end of December 2008. The negative price, when predicted and allowed in the market model structure at the energy exchange, mirrors the situation on the market in which the offer has significantly exceeded the demand. Although the achievement of the negative price on the electricity market is more of an exception than a rule, it is interesting to contemplate the reasons for such an unusual occurrence. Since its introduction onto the EEX, the negative market price has been achieved only a few times, mostly in particular hours at night when the consumption of electrical energy is normally reduced. The situation analysed in this work is interesting because the negative price was achieved in the period of a few successive hours and because of the achieved amounts of the negative price, so the work contemplates on possible causes which led to such a situation. Since European electrical power systems are well connected, an analysis has been performed and the work presents how the observed occurrences in western and middle Europe have impacted electricity flows in the Croatian electrical power system and its surroundings.

Ključne riječi: europska burza energije EEX; negativna cijena; spot tržište električne energije; tržišna cijena

Key words: electricity spot market; European Energy Exchange (EEX); market price; negative price

1 UVOD

Otvaranje tržišta električne energije u velikom broju europskih zemalja rezultiralo je s dva prevladavajuća načina trgovanja: putem bilateralnih ugovora (engl. *over the counter trading,* OTC *trading*) i putem organizirane burze električne energije (engl. *power exchange*). U prvom se slučaju svi uvjeti trgovanja dogovaraju između dviju ugovornih strana koje u potpunosti snose rizik međusobnog poslovanja. U drugom se slučaju trguje na organizirani i standardizirani način na središnjem mjestu trgovanja – burzi, gdje se prodavatelji i kupci anonimno susreću i sklapaju poslove posredstvom burze. U svakoj transakciji, bilo za prodaju bilo za kupnju električne energije, burza predstavlja drugu ugovornu stranu i preuzima rizik (engl. *counterparty risk*) te jamči fizičko i financijsko poravnanje (engl. *physical and financial clearing and settlement*). Burze električne energije su na početku svog poslovanja obično nudile trgovanje na spot tržištu dan unaprijed (engl. *spot electricity market, day-ahead electricity market*). Na spot tržištu se trguje električnom energijom koja se isporučuje sljedećeg dana i plaćanja se izvršavaju neposredno nakon obavljenog posla. S vremenom su, uobičajeno nakon uspješne uspostave spot tržišta, burze proširile svoju ponudu organizirajući financijsko tržište za električnu energiju na kojem se trguje izvedenicama tj. financijskim ugovorima (engl. *financial electricity market, derivatives electricity market*) koji pružaju mogućnost ograničavanja izloženosti riziku na tržištu. Mnoge od njih proširile su svoje poslovanje na druge energente i proizvode vezane uz energetiku (npr. prirodni plin, ugljen, emisije stakleničkih plinova) čime su se pretvorile u burze energije (engl. *energy exchanges*).

Uspostavom burzi i spot tržišta bilateralno trgovanje nije zanemareno, već se oba načina kupoprodaje električne energije istodobno i usporedno koriste. Na većini tržišta energije europskih zemalja najveći dio trgovine električnom energijom obavlja se dugoročnim bilateralnim ugovorima, dok se manji dio kratkoročne trgovine obavlja putem spot tržišta na burzi [1] i [2]. Bilateralnim se ugovorima obično podmiruju tzv. bazni i manje-više konstantni dijelovi dijagrama opterećenja (npr. blokovi noćne energije, blokovi dnevne vršne energije) za dulje vremensko razdoblje kao što su godina ili mjesec. Na spot tržištu se uobičajeno trguje manjim količinama električne energije za kraća vremenska razdoblja kao što su jedan sat ili blok od nekoliko sati, čime se nastoji popuniti preostali promjenjivi dio dijagrama opterećenja, jer se trguje u vremenu mnogo bližem isporuci kada se raspolaže s više boljih informacija i točnijim predviđanjima. Trgovanje na razini sata, primjerice, omogućava tržišnim sudionicima da uravnoteže svoj portfelj kupnje i prodaje električne energije u

1 INTRODUCTION

The opening of the electricity market has resulted in two prevailing trading methods in a large number of European countries: by virtue of over-the-counter trading (OTC trading) and by virtue of organized power exchange. In the former case, all trading conditions are agreed upon between the contracting parties which undertake the full risk of interoperability. In the latter case, trading is done in an organized and standardized manner at the central place of trading - the exchange, where sellers and buyers anonymously meet and conclude transactions through the exchange. In each transaction, either for the sale or for the purchase of electricity, the exchange represents the other contracting party and undertakes the counterparty risk and guarantees physical and financial clearing and settlement. At their beginnings, energy exchanges usually offered day-ahead spot electricity market trading. The trading on the spot market included electricity which was delivered the following day and payments which were performed immediately after the executed transaction. In time, usually after a successful establishment of the spot market, exchanges have widened their offers by organizing the financial electricity market where trading in derivatives, that is, financial contracts, takes place and these enable the limitation of exposure to risk on the market. Many of them have widened their business onto other energy sources and products related to energy (e.g. natural gas, coal, greenhouse gas emissions) which transformed them into energy exchanges.

The establishment of exchanges and spot markets did not neglect over-the-counter trading - both methods of purchase of electricity are used simultaneously and in parallel. On most of the energy markets of the European countries, most of the trading in electricity is done by virtue of over-the-counter trading, while a minor part of short-term trading is done by virtue of the spot exchange on the market [1] and [2]. Over-the-counter trading usually serves to settle the so-called basic and more or less constant parts of the load diagram (e.g. night energy blocks, daily peak energy blocks) for longer intervals of time such as a year or a month. The spot market usually serves for trading in smaller amounts of electricity for shorter periods of time such as an hour or a block of a few hours with the purpose to fill the remaining alterable part of the load diagram because the trading is done in the period much closer to the delivery when operators avail of more better-quality information and more precise forecasts. Trading on the level of an hour, for example, enables market participants to balance their electricity purchase and sale portfolio in the particular hour, while a combination of trading at the

određenom satu, dok se kombinacijom trgovanja na razini sata i blokovima energije može optimirati uporaba proizvodnih postrojenja. Neke burze organiziraju i tržište tijekom dana isporuke (engl. *intraday market*) koje tržišnim sudionicima daje mogućnost uravnoteženja njihove kupnje i prodaje električne energije u vremenu gotovo neposredno prije same isporuke (npr. 60, 75 ili 120 minuta prije isporuke). Na taj se način tržišnim sudionicima pruža fleksibilnost u trgovanju i ostvarenju ugovorenih obveza te daje prilika za smanjivanje troškova nerijetko skupe energije uravnoteženja, posebice u slučaju nepredviđenih događanja, kao što su neplanirane obustave rada ili ispadi iz pogona zbog kvarova postrojenja proizvođača ili krajnjih potrošača električne energije.

Osim već spomenute anonimnosti pri trgovanju, preuzimanja rizika te osiguravanja fizičkog i financijskog poravnanja, trgovanje putem burze pruža niz prednosti od kojih su najvažnije formiranje tržišne cijene (engl. *market clearing price)* i njena razvidnost te razvidnost ostalih informacija koje burza pruža tržišnim sudionicima. Cijena sa spot tržišta, ili kraće tržišna cijena, služi kao referenca za cijene na svim drugim tržištima kao što su financijsko tržište, bilateralno trgovanje, tržište energije uravnoteženja ili ugovaranje prodaje električne energije krajnjim potrošačima [1] i [2]. Nadalje, trend promjene tržišne cijene daje signale za buduća ulaganja u proizvodna postrojenja: rastući trend ukazuje na potrebu za ulaganjima, a padajući upravo obrnuto. Također, u razdoblju smanjene ili oskudne ponude električne energije velika tržišna cijena može potaći potrošače na smanjivanje njihove potrošnje.

U ovom je radu pozornost usmjerena na jedan detalj vezan uz tržišnu cijenu električne energije na spot tržištu europske burze energije EEX (engl. *European Energy Exchange*, EEX) koji je zabilježen krajem prosinca 2008. godine. Početkom četvrtog tjedna prosinca u nekoliko uzastopnih sati noću te za blokove energije tijekom noćnih sati tržišna cijena postigla je zamjetan negativan iznos. Tržišna cijena električne energije je uobičajeno pozitivnog iznosa i odražava uravnoteženost ponude i potražnje, odnosno prodaje (proizvodnje) i kupnje (potrošnje) električne energije. U takvoj situaciji kupac plaća prodavatelju kupljeni proizvod po tržišnoj cijeni. Negativna cijena znači da prodavatelj prodaje električnu energiju kupcu i za to plaća umjesto da biva plaćen. Ili, drugim riječima, kupac dobiva kupljenu energiju, ali istodobno, umjesto da plaća za proizvod, kupac dobiva i novac. Na temelju javno dostupnih podataka i informacija te saznanja autora u radu se nastojalo dati odgovore na pitanja kako se i zašto postigla negativna tržišna cijena. Usporedbe radi, u radu su razmatrana zbivanja u trećem i četvrtom tjednu prosinca 2008. godine.

level of an hour and in energy blocks can optimize the use of production facilities. Some exchanges also organize the intraday market which gives the market participants the possibility of adjustment of their purchase and sale of electricity in a period almost immediately before the delivery itself (e.g. 60, 75 or 120 minutes before delivery). This method provides market participants with flexibility in trading and realization of contracted obligations and a chance for reduction of costs of often very expensive balance energy, especially in the case of unforeseen events, such as unplanned work discontinuations or operation failures due to faults of the plant or end electricity consumers.

Besides the already mentioned anonymity at trading, undertaking of risk and provision of physical and financial settlement, trading through the exchange offers a number of advantages of which the most important are the market clearing price and its conspicuousness and the conspicuousness of the other information offered by the exchange to the market participants. The spot market price, or, shorter, the market price, serves as a reference for the prices on all the other markets such as the financial market, over-the-counter trading, balance energy trading or contracting the sale of electricity to end consumers [1] and [2]. Furthermore, the trend of market price alterations provides signals for future investments into production facilities: the growing trend points to a need for investments, and the falling trend exactly to the opposite. Moreover, in the period of reduced or sparse offer of electricity, a high market price may encourage consumers to reduce the consumption.

In this work, the focus is on one detail related to the electricity market price on the European Energy Exchange (EEX) which was recorded at the end of December 2008. At the beginning of the fourth week of December in several consecutive hours at night, as well as for energy blocks during night hours, the market price achieved a significant negative amount. The electricity market price is usually of positive amount and it represents the balance between offer and demand, that is, sale (production) and purchase (supply) of electricity. In such case the buyer pays the seller the purchased product at the market price. Negative price means that the seller sells (supplies) energy to the buyer and pays for it, instead of being paid for it. Or, in other words, the buyer gets (takes over) the purchased energy, but at the same time, instead of paying for the product, the buyer also gets the money. Based on publicly available data and information and the author's cognitions, the work aimed to provide answers to the questions about why and how was the negative market price achieved. For the purpose of comparison, the work reviews the events in the third and fourth week of December 2008.

U nastavku rada ukratko su opisani pravilo određivanja tržišne cijene koje prevladava u europskim zemljama te europska burza energije EEX, nakon čega slijedi razmatranje konkretne pojave negativne cijene. Na kraju rada predočena su događanja u hrvatskom elektroenergetskom sustavu (EES-u) krajem 2008. godine te kakav je bio utjecaj razmatrane situacije u zapadnoj i središnjoj Europi na tokove snaga u hrvatskom EES-u i njegovom neposrednom susjedstvu.

2 ODREĐIVANJE CIJENE NA SPOT TRŽIŠTU

Većina burzi trgovanje na spot tržištu organizira i provodi kroz središnju aukciju (dražbu) koja se održava nakon isteka vremena za podnošenje ponuda. Osim toga, neke burze za određene proizvode nude i tzv. kontinuirani način trgovanja (engl. *continuous trading*) u kojem se prispjele ponude odmah nalaze na tržištu. U tom načinu trgovanja kada se pronađu međusobno odgovarajuće ponude za kupnju i prodaju električne energije (engl. *matching bids*) one se odmah realiziraju. U aukcijskom (dražbenom) načinu trgovanja za izračunavanje tržišne cijene prevladava tzv. pravilo jedinstvene cijene (engl. *uniform price rule*) u kojem se cijena određuje temeljem svih prodajnih i kupovnih ponuda svih tržišnih sudionika. Od svih pristiglih ponuda za kupnju i za prodaju električne energije formiraju se za svaki sat sljedećeg dana ukupna krivulja ponude (prodaje) i ukupna krivulja potražnje (kupnje). Sjecište ovih dviju krivulja za svaki sat sljedećeg dana definira tržišnu cijenu (engl. *market clearing price*) i ukupnu količinu trgovane električne energije (engl. *market clearing volume*) u satu.

Slika 1 prikazuje primjer određivanja tržišne cijene na burzi APX u Amsterdamu – za dan 23. siječnja 2006. godine tržišna cijena u 16-om satu (od 15:00 do 16:00 sati) iznosila je 81,83 EUR/MWh, a ukupni volumen trgovanja 2 023,5 MWh. U svakom satu svaki kupac za električnu energiju plaća tržišnu cijenu određenu za taj sat, a ista se cijena plaća za električnu energiju prodavatelju. Dakle, u svakom satu svi tržišni sudionici trguju električnom energijom prema istoj jedinstvenoj cijeni.

2.1 Gornja i donja granica cijene na spot tržištu

Na većini spot tržišta gdje se provodi središnja aukcija (dražba) definirane su gornja i donja granica za tržišnu cijenu, odnosno tzv. granične cijene: najveća tržišna cijena (engl. *maximum market price, market price cap*) i najmanja tržišna cijena (engl. *minimum market price, market price floor*). Određivanje njihovog iznosa, posebice najveće tr-

The remainder of the work shortly describes the rule for the determination of the market price prevailing in European countries and the European Energy Exchange, after which an analysis of the actual occurrence of a negative price follows. At the end of the work, events are presented in the Croatian electrical power system which happened at the end of 2008, as well as the impact of the observed situation in western and middle Europe on power flows in the Croatian electrical power system and its direct vicinity.

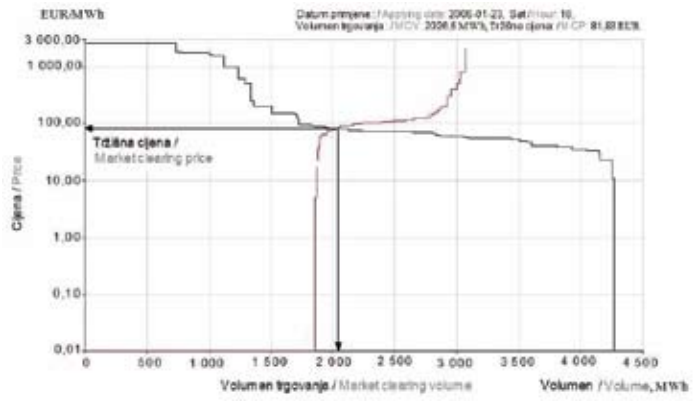
2 SPOT MARKET PRICES CLEARING

Most exchanges organize and undertake the trading on the spot market through a central auction which is held after the expiry of the deadline for submission of bids. Other than this, some exchanges offer the so-called continuous trading method by virtue of which the received bids are put on the market immediately. With such a trading method, when mutually agreeable purchase and sale bids are found, they are immediately realized. In the auction trading method, the market prices are mostly calculated according to the so-called uniform price rule in which the price is set based on all sale and purchase offers of all the market participants. Based on all received bids for purchase and sale of electricity, for each hour of the following day, an overall curve of offer (sale) and an overall curve of demand (purchase) are formed. The intersection of these two curves for each hour of the following day defines the market clearing price and the total market clearing volume in an hour.

Figure 1 shows an example of determination of the market price on the APX exchange in Amsterdam - for the 23rd day of January 2006, market price in the 16th hour (from 15:00 to 16:00 hours) amounted to 81,83 EUR/MWh, and the total market clearing volume was 2 023,5 MWh. In each hour, each buyer pays the market price defined for electricity for that hour, and the same price is paid for electricity to the seller. Therefore, in each hour, all market participants trade in electricity according to the same uniform price.

2.1 Maximum and minimum market prices

On most spot markets where central auction is undertaken, the top and bottom limits of market prices are defined, that is, the so-called cut-off prices: the maximum market price and the minimum market price. Determination of their amount, especially the maximum market price, on an imperfect market such as the electricity market is not at all simple. One should be very care-



Slika 1 — Primjer određivanja cijene na spot tržištu [3]
Figure 1 — Example of spot price calculation [3]

žišne cijene, na nesavršenom tržištu kakvo je tržište električne energije nije nimalo jednostavno. Treba biti vrlo oprezan kako bi se izbjegli negativni, a postigli pozitivni učinci za tržišne sudionike. Zato burze moraju redovito provjeravati jesu li iznosi gornje i donje granice za tržišnu cijenu primjereni te ih po potrebi prilagođavati uvjetima na tržištu električne energije [2].

Ponekad se može dogoditi da sjecište krivulje ukupne ponude i krivulje ukupne potražnje na spot tržištu nije moguće odrediti. Takve se situacije pojavljuju kada na tržištu postoji prevelika ponuda (premala potražnja) ili premala ponuda (prevelika potražnja) električne energije. Prevelika se ponuda obično rješava razmjernim ograničavanjem prodajnih ponuda tako da se krivulje ponude i potražnje presijeku uz najmanju cijenu (slika 2), a prevelika potražnja razmjernim ograničavanjem kupovnih ponuda tako da se krivulje ponude i potražnje presijeku uz najveću cijenu [4]. U oba se slučaja ukupno ograničenje razmjerno raspodjeljuje na tržišne sudionike što znači da će moći prodati odnosno kupiti samo dio električne energije iz svojih ponuda. Neke burze ovakve situacije nastoje riješiti organiziranjem ponovnog prikupljanja novih ponuda tržišnih sudionika i nove središnje aukcije (dražbe). Ako se nakon drugog kruga opet ne može odrediti tržišna cijena, poseže se za razmjernim ograničavanjem [5].

Najmanja tržišna cijena često je 0 EUR/MWh iako nije u skladu sa strukturom troškova proizvodnje električne energije [2], a na nekim je tržištima negativnog iznosa [5] i [6]. Ograničavanje prodajnih ponuda uz cijenu 0 EUR/MWh može prodavateljima izazvati značajne troškove energije uravnoteženja. Zbog toga je prodavateljima odnosno proizvođačima električne energije ponekad ekonomski opravdano da u svojim ponudama za prodaju navode negativne cijene. Oni time pokazuju da su voljni platiti kako bi isporučili svoj proizvod na tržištu te izbjegli moguće dodatne troškove.

ful to avoid negative and achieve positive effects for market participants. The exchanges should therefore check if the amounts of the top and bottom limits are suitable for the market price and adjust them, if necessary, to the conditions on the electricity market [2].

Sometimes it is impossible to define the intersection of the overall offer and overall demand curve on the spot market. Such situations occur when there is excessive offer (insufficient demand) on the market or insufficient offer (excessive demand) of electricity. Excessive offer is usually resolved by proportionate limitation of sales offers so as to intersect the curves of offer and demand along the minimum price (Figure 2), and excessive demand by proportionate limitation of purchase offers so as to intersect the curves of offer and demand along the maximum price [4]. In both cases, the total limitation is proportionately divided onto market participants, which means they will be able to sell or purchase only a part of the electricity from their bids. Some exchanges try to resolve these kinds of situations by organizing a repeated collection of new bids from market participants and new central auctions. If, after a second cycle, the market price cannot be defined again, proportionate limitation is used [5].

The minimum market price is often 0 EUR/MWh although it does not conform to the structure of costs for the production of electricity [2], and in some markets it has a negative amount [5] and [6]. Limitation of sales bids with the price of 0 EUR/MWh may incur significant costs of balance energy for sellers. Therefore, it is sometimes economically justifiable for sellers, that is, producers of electricity to state negative prices in their sales bids. In such way they show that they are willing to pay to dispatch their product onto the market and avoid possible additional costs.

Slika 2 — Ograničavanje ponude uz najmanju cijenu [4]
Figure 2 — Curtailment of sales bids at minimum price [4]

Negativna cijena na tržištu električne energije nije novost niti nepoznanica. Ona već postoji u strukturi nekih kratkoročnih tržišta kao što je tržište energije uravnoteženja [7], spot tržište [6] ili tržište tijekom dana isporuke. Pojavu negativne cijene na spot tržištu može se očekivati u kraćim razdobljima noću, jer je obično od ponoći do ranih jutarnjih sati (od 00:00 do 06:00 sati) potrošnja električne energije najmanja. Smanjenu potrošnju u noćnim satima proizvodnja električne energije može nadmašiti zbog rada postrojenja koja se ne stavljaju izvan pogona zbog njihovih tehničkih karakteristika ili zbog prevelikih troškova njihovog zaustavljanja i ponovnog pokretanja, ili primjerice zbog rada CHP postrojenja koja prvenstveno proizvode toplinu (paru), a električnu energiju kao nusproizvod. Ponekad se negativna cijena može pojaviti kroz dulja vremenska razdoblja i postići velike iznose [6] i [7].

Govoreći općenito o promjeni cijene električne energije tijekom dana, temeljem iskustvenih spoznaja može se reći: ako cijena električne energije približno prati dnevni dijagram opterećenja EES-a, tada nema poremećaja niti posebnih utjecaja koji bi uzrokovali njenu promjenu. Ako se dogodi bilo kakav poremećaj, odnosno ako postoji određeni električki ili neelektrički utjecaj, cijena električne energije reagira većim odstupanjima. Tako, primjerice, veći poremećaj u nekom od susjednih EES-a, poput raspada ili sloma dijela EES-a, može uzrokovati poremećaj cijene na spot tržištu. Takav se primjer dogodio u lipnju 2006. godine kada je u razdoblju vrlo visokih dnevnih temperatura zraka došlo do poremećaja u poljskom EES-u, na što su cijene električne energije na spot tržištu reagirale promptno i višestruko premašile sve dotad postignute iznose.

Negative price on the electricity market is neither new nor unknown. It already exists in the structure of some short-term markets such as the balance energy market [7], the spot market [6] or the intraday market. The occurrence of the negative price on the spot market may be expected in shorter periods of time at night because energy consumption is usually at its lowest from midnight until early morning hours (from 00:00 to 6:00 hours). Production of electricity may overcome reduced consumption in the night hours because of the operation of the facilities which are not put out of operation because of their technical characteristics or excessive costs of stopping and actuating them again, or, for example, because of the operation of the CHP facilities which primarily produce heat (steam), and which produce electricity as a by-product. Sometimes the negative price may occur through longer periods of time and achieve high amounts [6] and [7].

Talking about the alterations of electricity prices during the day, based on experience, it can be said: if the electricity price approximately follows the daily load diagram of the electrical power system, then there are no disruptions or special impacts which might cause its alteration. In case of any disruptions, that is, if there is a certain electrical or non-electrical impact, the electricity price will react with greater derogations. Thus, for example, a significant disruption in one of the neighbouring electrical power systems, such as a blackout or failure of part of the electrical power system, may cause a disruption of the spot market price. Such event occurred in June 2006 when in the period of very high daily air temperatures, there occurred a disruption in the Polish electrical power system which was followed by a prompt reaction of the electricity prices on the spot market which multiply exceeded all the amounts achieved thus far.

3 NEGATIVNA CIJENA ELEKTRIČNE ENERGIJE NA SPOT TRŽIŠTU EEX-A

3.1 Europska burza energije EEX

Europska burza energije EEX stvorena je 2002. godine spajanjem burze električne energije LPX sa sjedištem u Leipzigu (engl. *Leipzig Power Exchange*) i europske burze energije EEX sa sjedištem u Frankfurtu u jedinstvenu europsku burzu energije EEX AG sa sjedištem u Leipzigu (u daljnjem tekstu: EEX). Isprva je poslovanje bilo usredotočeno na trgovanje električnom energijom, a danas obuhvaća prirodni plin, ugljen te tržište emisijama CO_2. U početku se električnom energijom moglo trgovati samo unutar Njemačke, da bi se u travnju 2005. godine područje trgovanja proširilo na regulacijsko područje APG (engl. *Austrian Power Grid*) u Austriji koje zajedno s Njemačkom čini jedno područje trgovanja (engl. *market area*). U prosincu 2006. godine trgovanje na EEX-u je prošireno na područje Švicarske koje čini zasebno područje trgovanja. Danas se na EEX-u nudi organizirano trgovanje:

— električnom energijom na spot tržištu, financijskom tržištu i tržištu tijekom dana isporuke,
— prirodnim plinom na spot tržištu i financijskom tržištu,
— emisijama CO_2 na spot tržištu i financijskom tržištu,
— ugljenom na financijskom tržištu.

U kratkom razdoblju od svog nastanka do danas, u nešto više od 6 godina, EEX se razvila iz lokalne burze električne energije u jednu od najznačajnijih burzi energije u kontinentalnoj Europi. Prema posljednjim podacima s internetskih stranica EEX-a [5] danas na ovoj burzi energije trguje više od 200 tvrtki iz 19 zemalja. Misao vodilja EEX-a je povezivanje tržišta (engl. *connecting markets*) u skladu s kojom EEX neprestano širi paletu energenata i proizvoda koje nudi na svojim tržištima te poslovanje glede zemljopisnog opsega i međunarodne suradnje, čime učvršćuje i širi svoj tržišni položaj.

EEX pruža mogućnost trgovanja električnom energijom za različita vremenska razdoblja u sustavu međusobno povezanih i ovisnih tržišta, u kojem spot tržište ima središnju ulogu. Na spot tržištu EEX-a trguje se tzv. spot ugovorima koji su, s obzirom na vremensko razdoblje isporuke električne energije, ili satni (engl. *hourly contracts*) ili blok ugovori (engl. *block contracts, blocks*) [8].

U satnom se ugovoru trguje električnom energijom konstantnog iznosa snage u jednom satu, dok se u blok ugovoru trguje električnom energijom konstantnog iznosa snage u nekoliko uzastopnih sati. Volumen trgovanja u ugovoru, odnosno količina

3 NEGATIVE PRICE OF ELECTRICITY ON THE EEX SPOT MARKET

3.1 European Energy Exchange (EEX)

The European Energy Exchange EEX was established in 2002 by a merger of the Leipzig Power Exchange and the European Energy Exchange EEX seated in Frankfurt into one single European Energy Exchange EEX AG seated in Leipzig (hereinafter: EEX). The business was first focussed on electricity trade, and now it encompasses natural gas, coal and the CO_2 emissions market. In the beginning, trading in electricity could only be done within Germany; in April 2005 the trading area spread onto the Austrian Power Grid regulation area in Austria which, together with Germany, constitutes a single market area. In December 2006, trading at the EEX was widened onto the Switzerland territory which constitutes a separate market area. Today, EEX offers organized trading:

— in electricity on the spot market, financial market and the intraday market,
— in natural gas on the spot market and the financial market,
— in CO_2 emissions on the spot market and the financial market,
— in coal on the financial market.

In the short period since its establishment up to today, in just over 6 years, the EEX has developed from a local electricity market into one of the most significant energy markets in continental Europe. According to recent data from the EEX web pages [5], more than 200 companies from 19 countries trade at this energy exchange. The EEX's guiding idea of connecting markets is what the EEX continuously follows in order to widen its energy sources and products line up offered on its markets, and to widen its business as regards its geographical radius and international cooperation by which it reinforces and widens its market position.

The EEX offers the possibility of trading in electricity for different periods of time in a system of interrelated and interdependent markets; the spot market has the pivotal role in this. On the EEX's spot market, trading is done in so-called spot contracts which are, as regards the period of time of delivery of electricity, either hourly contracts or block contracts [8].

The hourly contract serves for trading in electricity of constant power amount in one hour, while the block contract serves for trading in electricity of constant power amount in a few consecutive

električne energije kojom se trguje određuje se kao umnožak navedene snage i broja sati isporuke. Blok ugovori, ili blok proizvodi, mogu biti standardizirani ili ih u svojim ponudama mogu definirati sami tržišni sudionici. Volumen trgovanja na spot tržištu EEX-a dosegao je oko 15 % ukupne godišnje potrošnje električne energije na području trgovanja EEX-a, a raste iz godine u godinu. Izuzmu li se nordijska burza Nord Pool i burza na Iberijskom poluotoku, ovo je vrlo dobar rezultat u usporedbi s nekim drugim burzama u Europi (primjerice, taj omjer na britanskoj burzi APX UK iznosi oko 2 %, na francuskoj burzi Powernext oko 3 %, na nizozemskoj burzi APX NL oko 12 %) [2].

Na spot tržištu EEX-a gornja granica tržišne cijene bila je i ostala 3 000,0 EUR/MWh, dok je donja granica promijenjena s iznosa 0,0 EUR/MWh na – 3 000,0 EUR/MWh. Pokazalo se da je gornja granica prilično dobro određena i dosada na EEX-u nije zabilježeno ograničavanje ponuda za kupnju električne energije. S druge strane, potreba za promjenom iznosa donje granice i uvođenjem negativne cijene pojavila se zbog nekoliko razloga. U određenim situacijama ponuda na tržištu može biti veća od potražnje uz cijenu 0,0 EUR/MWh. To su, primjerice, situacije u kojima se velika proizvodnja električne energije vjetroelektrana u Njemačkoj ostvaruje u satima smanjene potrošnje.

Takav odnos proizvodnje i potrošnje, odnosno ponude i potražnje može rezultirati razmjernim ograničavanjem ponuda za prodaju električne energije. Na EEX-u to konkretno znači da neke blok ponude neće biti prihvaćene te da će prodavatelji moći prodati samo dio električne energije iz svojih ponuda satnih ugovora. Osim prodavatelja koji nastoje prodati svoje kratkoročne viškove energije putem spot tržišta, razmjerno ograničavanje prodajnih ponuda zahvaća i one tržišne sudionike koji su ranije osigurali svoje fizičke portfelje putem financijskih ugovora, primjerice ročnica (engl. *future contracts, futures*), a sad ih namjeravaju namiriti putem spot tržišta.

EEX kao burza mora jamčiti, u najvećoj mogućoj mjeri, ispunjavanje ugovora sklopljenih posredstvom burze te da međusobno povezani načini trgovanja ponuđeni na burzi pravilno i dobro funkcioniraju. Zbog svega navedenog na EEX-u je odlučeno promijeniti donju granicu cijene na negativan iznos te omogućiti tržišnim sudionicima da u svojim ponudama navode negativne cijene, što u konačnici može rezultirati negativnom cijenom na spot tržištu [9] i [10]. Negativna cijena na EEX-u najprije je uvedena na tržištu tijekom dana isporuke [11], a zatim i na spot tržištu [12] i [13]. Zanimljivo je napomenuti da Nord Pool uskoro namjerava uvesti negativnu cijenu

hours. The volume of trading in the contract, that is, the quantity of electricity which is the subject of the trade, is calculated as a product of the stated power and the number of supply hours. Block contracts, or block products, may be standardized or defined in the bids of the market participants themselves. Trading volume on the EEX's spot market reached about 15 % of the total annual power consumption on the EEX's market area and it increases year after year. If the Nord Pool Nordic exchange and the exchange on the Iberian peninsula are excluded, this is a very good result in comparison to some other exchanges in Europe (for example, that ratio on the British APX UK exchange amounts to about 2 %, on the French Powernext exchange to about 3 %, and on the Netherlands APX NL exchange to about 12 %) [2].

On the EEX's spot market, the top market price limit was, and still is, 3 000,0 EUR/MWh, while the bottom limit was changed from the amount of 0,0 EUR/MWh to – 3 000,0 EUR/MWh. The top limit appears to be well determined and so far limitation of bids for purchase of electricity has not been recorded at the EEX. On the other hand, the need for changing the amount of the bottom limit and for the introduction of the negative price occurred for a few reasons. In certain situations the offer on the market may be greater than the demand at the price 0,0 EUR/MWh. An example of such situation is when high energy production of wind power plants in Germany is realized in the hours of reduced consumption.

Such relation between production and consumption, that is, offer and demand, may result in proportionate limitation of offers for sale of electricity. At the EEX, this particularly means that certain block offers will not be accepted and that the sellers will be able to sell only a part of electricity from their hourly contract offers. Besides the sellers who strive to sell their short-term energy surpluses through the spot market, proportionate limitation of sales bids encompasses also those market participants who ensured their physical portfolios through financial contracts earlier, for example, through future contracts, and now they intend to settle them through the spot market.

As an exchange, the EEX must guarantee, to the maximum extent, fulfillment of contracts concluded by virtue of the exchange and that interrelated trading methods are duly offered on the exchange and that they are functioning well. Due to all of the above, the EEX decided to change the bottom price limit to a negative amount and enable market participants to state negative prices in their offers, which can eventually result in a negative price on the spot market [9] [10]. Negative price at the EEX was first introduced onto the intraday market [11], and then also onto the spot market [12] and [13]. It is interesting to state that Nord Pool intends to in-

na spot tržištu električne energije u iznosu od – 200,0 EUR/MWh, posebice zbog učestalih zahtjeva tržišnih sudionika iz Danske gdje je velik udio proizvodnje iz vjetroelektrana.

3.2 Cijena električne energije i volumen trgovanja na spot tržištu EEX-a u prosincu 2008. godine

U radu je razmatrana cijena električne energije i volumen trgovanja na spot tržištu EEX-a tijekom prosinca 2008. godine. Nizom tabličnih i grafičkih prikaza predočene su njihove promjene tijekom mjeseca, tjedna te dana. Podaci korišteni u analizama preuzeti su s internetskih stranica EEX-a [5]. Predočena je međusobna zavisnost cijene i volumena te istaknuto neobično odstupanje cijene u ponedjeljak 22. prosinca 2008. godine u odnosu na isti dan i sate tjedan dana ranije. Radi usporedbe razmatrana su i predočena dva uzastopna tjedna u prosincu 2008. godine. Neobično odstupanje cijene ostvareno je u noćnim satima kada je potrošnja električne energije najmanja. Stoga su u razmatranju posebno izdvojeni i prikazani sati najmanje potrošnje energije tijekom dana: treći (od 02:00 do 03:00), četvrti (od 03:00 do 04:00) i peti sat (od 04:00 do 05:00).

Slikama od 3 do 12 predočene su promjene cijena električne energije u prosincu 2008. godine za različita vremenska razdoblja: od cijelog mjeseca do jednog dana, odnosno odabranih sati. Slike duljih vremenskih razdoblja predočavaju i trend promjene cijene. Na slikama 9, 10, 11 i 12 izdvojene su i prikazane cijene samo za razdoblje smanjene potrošnje električne energije.

Slika 3 prikazuje promjenu satnih cijena električne energije u trećem, četvrtom i petom satu tijekom cijelog prosinca 2008. godine. To su sati najmanjeg opterećenja elektroenergetskog sustava, upravo kada su cijene postigle neobične iznose. Analizirajući cijene za navedene sate tijekom cijelog prosinca uočeno je zadržavanje na manje-više konstantnoj razini tijekom duljeg razdoblja i veliki propad na negativne iznose u ponedjeljak 22. prosinca. Tada su cijene postigle najmanje iznose u povijesti burze EEX. Pad cijena na ovu razinu nije se dogodio iznenada i slučajno.

Slika 4 prikazuje niz satnih cijena tijekom trećeg i četvrtog tjedna prosinca u kojem je prepoznatljiv dnevni uzorak promjene cijene električne energije. Na slici je vidljiv padajući trend cijene. U trećem tjednu cijena se postupno smanjivala prema danima vikenda kada je postigla najmanje iznose. U četvrtom tjednu, osim izrazito velike negativne cijene u jutarnjim satima ponedjeljka, najmanji iznosi cijene postignuti su u vrijeme božićnih blagdana sredinom tjedna, nakon čega se cijena vratila na uobičajenu razinu tijekom vikenda.

troduce the negative price soon onto the electricity spot market in the amount of – 200,0 EUR/MWh, especially due to frequent requests of market participants from Denmark where a large share of the production is covered by the wind power plants.

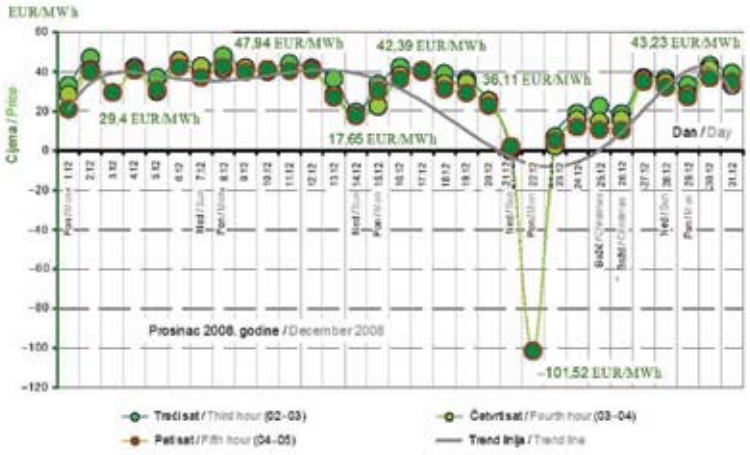
3.2 Electricity price and trading volume on the EEX spot market in December 2008

The work analysed the electricity price and trading volume on the EEX spot market during December 2008. A number of tabular and numerical figures presented their changes during the month, the week and the day. Data used in the analyses were taken over from the EEX's web pages [5]. Interdependency of price and volume is presented and unusual deviation of price on Monday 22 December 2008 is pointed out in relation to the same day and hour a week earlier. For the purpose of comparison, two consecutive weeks in December 2008 are observed. Unusual deviation of price was realized in the night hours when electricity consumption was at its lowest. Therefore, the observation especially singles out and presents the hours of minimum energy consumption during the day: the third (02:00 until 03:00), the fourth (03:00 until 04:00) and the fifth hour (04:00 until 05:00).

Figures 3 to 12 present changes in electricity prices in December 2008 for different periods of time: from a month to one day, that is, selected hours. Figures of longer periods of time present the price change trend as well. Figures 9, 10, 11 and 12 single out and show prices only for the period of reduced energy consumption.

Figure 3 shows a change of hourly prices of electricity in the third, fourth ad fifth hour throughout December 2008. Those are the hours of minimum electrical power system load, and exactly when the prices reached unusual amounts. The analysis of the prices for the above hours during the entire December revealed a lingering on a more or less constant level during a longer period of time and a large fall to negative prices on Monday 22 December. At that time, the prices reached the lowest amounts in the history of the EEX. A fall of the prices to this level happened neither suddenly nor accidentally.

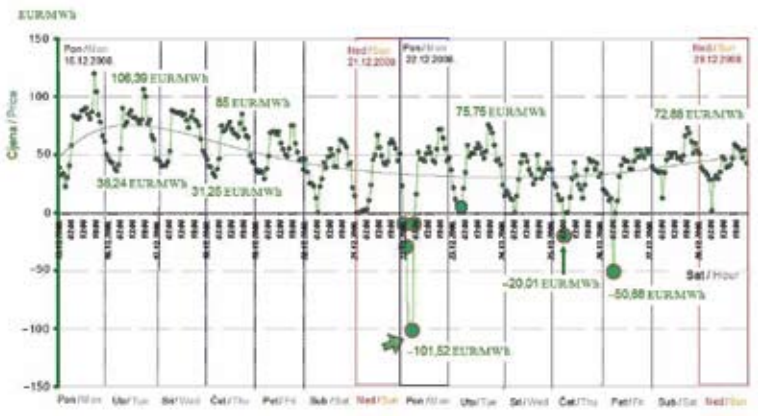
Figure 4 shows a number of hourly prices during the third and fourth week of December in which a daily pattern of electricity price changes is evident. The figure reveals a falling price trend. In the third week, the price was gradually falling towards the weekend days when it reached the lowest amounts. In the fourth week, besides an exceptionally high negative price in the morning hours of Monday, the lowest price amounts were achieved at the time of Christmas holidays in the middle of the week, after which the price returned to the normal level during the weekend.



Slika 3 — Cijene električne energije na EEX-u tijekom noći u vrijeme smanjene potrošnje u prosincu 2008. godine [5]
Figure 3 — Electricity prices on EEX at night during a low consumption period in December 2008 [5]

U istom razdoblju negativne cijene su postignute i za neke standardizirane blok proizvode koji se nude na EEX-u. Cijene postignute za standardizirane blok proizvode u trećem i četvrtom tjednu prosinca prikazane su tablicama 1 i 2, dok su promjene cijena na satnoj razini prikazane tablicama 3 i 4 te slikama od 4 do 8. U tablicama 1 i 2 pored naziva blok proizvoda u zagradama je navedeno i njegovo vremensko razdoblje. U tablicama je namjerno prikazano sedmodnevno razdoblje od petka u jednom tjednu do četvrtka idućeg tjedna radi isticanja neobičnog odstupanja cijena u ponedjeljak 22. prosinca 2008. godine u odnosu na dane neposredno ispred i neposredno nakon. Premda prikazana razdoblja nisu kalendarski tjedni, u radu su nazvani trećim i četvrtim tjednom u prosincu 2008. godine. U četvrtom tjednu (tablica 2) ističe se ponedjeljak 22. prosinca zbog pojave negativnih cijena blok proizvoda Offpeak, Offpeak I te Night. Također, negativna cijena je postignuta za blok proizvod Morning na božićne blagdane: u četvrtak 25. prosinca (– 1,62 EUR/MWh) te u petak 26. prosinca (– 2,54 EUR/MWh). U trećem tjednu prosinca (tablica 1) istaknut je, radi usporedbe, ponedjeljak 15. prosinca. Razlika u cijenama odgovarajućih blok proizvoda uglavnom se kretala od deset do dvadeset posto, a za dva uspoređena ponedjeljka razlika u cijenama je znatno veća.

In the same period, negative prices were reached also for some standardized block products offered at the EEX. Prices achieved for standardized block products in the third and fourth week of December are shown in Tables 1 and 2, while price changes at the hourly level are shown in Tables 3 and 4 and in Figures 4 to 8. In Tables 1 and 2, beside the name of the block products, its period of time is also stated in brackets. The tables intentionally state a seven-day period from Friday in one week until Thursday of the other week for the purpose of accentuating an unusual price deviation on Monday 22 December 2008 in relation to the immediately preceding days and those immediately after. Although the periods shown are not calendar weeks, the work calls them the third and the fourth week in December 2008. In the fourth week (Table 2), Monday 22 December stands out because of the occurrence of negative prices of block products Offpeak, Offpeak I and Night. Moreover, the negative price was also achieved for the block product Morning on Christmas holidays: On Thursday, 25 December (– 1,62 EUR/MWh) and on Friday, 26 December (– 2,54 EUR/MWh). In the third week of December (Table 1), for the purpose of comparison, Monday, 15 December is highlighted. The difference in prices of relevant block products fluctuated mostly from ten to twenty percent, and for the two Mondays compared, the difference in prices was much greater.



Slika 4 — Satne cijene električne energije na EEX-u u trećem i četvrtom tjednu prosinca 2008. godine [5]
Figure 4 — Hourly electricity prices on EEX in the third and the fourth week of December 2008 [5]

Tablica 1 – Cijene blok proizvoda, EUR/MWh na EEX-u u razdoblju od 12.12.2008. do 18.12.2008. [5]
Table 1 – Price of blocks products, EUR/MWh on the EEX from 12 December 2008 to 18 December 2008 [5]

Blok proizvodi / Blocks:		Cijene blok proizvoda / Prices of block products, EUR/MWh						
		Pet / Fri	Sub / Sat	Ned / Sun	Pon / Mon	Uto / Tue	Sri / Wed	Čet / Thu
		12.12.2008.	13.12.2008.	14.12.2008.	15.12.2008.	16.12.2008.	17.12.2008.	18.12.2008.
Offpeak	(20:00–08:00)	–	–	–	–	–	–	–
Offpeak I	(00:00–08:00)	51,77	31,72	15,20	42,45	49,13	49,59	43,62
Offpeak II	(20:00–24:00	58,57	40,48	46,90	63,91	63,84	60,52	50,13
Night	(00:00–06:00)	42,63	32,75	16,72	33,00	41,30	42,53	37,92
Morning	(00:06–10:00	85,34	37,56	17,53	76,15	74,58	78,90	65,78
High noon	(10:00–14:00)	90,85	49,39	42,04	87,27	84,34	85,30	73,41
Afternoon	(14:00–18:00)	87,75	48,60	46,12	93,20	85,72	80,79	73,74
Rush hour	(16:00–20:00)	86,52	57,91	56,44	99,02	90,86	82,30	75,04
Evening	(18:00–24:00)	65,24	46,19	51,16	74,06	72,06	66,81	56,44
Business	(08:00–16:00)	88,55	46,07	36,88	84,69	80,85	83,51	71,02

Tablica 2 – Cijene blok proizvoda, EUR/MWh na EEX-u u razdoblju od 19.12.2008. do 25.12.2008. [5]
Table 2 - Price of block products, EUR/MWh on the EEX from 19 December 2008 to 25 December 2008 [5]

Blok proizvodi / Blocks:		Cijene blok proizvoda / Prices of block products, EUR/MWh						
		Pet / Fri	Sub / Sat	Ned / Sun	Pon / Mon	Uto / Tue	Sri / Wed	Čet / Thu
		19.12.2008.	20.12.2008.	21.12.2008.	22.12.2008.	23.12.2008.	24.12.2008.	25.12.2008.
Offpeak	(20:00–08:00)	–	29,38	17,31	–8,51	29,35	21,83	21,34
Offpeak I	(00:00–08:00)	40,89	23,78	4,21	–35,77	20,17	13,83	12,66
Offpeak II	(20:00–24:00)	45,17	40,58	43,50	46,03	47,71	37,84	38,72
Night	(00:00–06:00)	34,93	27,89	3,43	–59,02	11,38	16,04	20,22
Morning	(06:00–10:00)	64,40	23,91	20,66	40,20	48,22	21,54	–1,62
High noon	(10:00–14:00)	63,08	47,89	55,42	50,82	55,32	44,92	32,19
Afternoon	(14:00–18:00)	57,33	48,68	47,09	53,75	56,80	34,25	23,30
Rush hour	(16:00–20:00)	66,38	59,52	56,73	65,64	67,60	36,57	37,79
Evening	(18:00–24:00)	52,63	47,38	49,49	53,33	55,36	36,38	40,89
Business	(08:00–16:00)	61,41	42,86	46,94	48,05	52,40	38,64	21,85

Tablice 3 i 4 prikazuju satne cijene i volumene trgovanja za dva uspoređena tjedna, pri čemu su istaknuti iznosi za dva uzastopna ponedjeljka. Tijekom noći, odnosno ranih jutarnjih sati (od 00:00 do 06:00 sati) 22. prosinca ostvarene su negativne cijene električne energije na spot tržištu EEX-a, a najveći negativni iznosi ostvareni su u trećem, četvrtom i petom satu (slike 7 i 8). U dnevnom dijagramu opterećenja EES-a, koji ujedno predočava i potrošnju električne energije, vremensko razdoblje od ponoći do 6 sati ujutro je razdoblje najmanje potrošnje električne energije. Pojava veće

Tables 3 and 4 show hourly prices and trading volumes for two compared weeks, whereat amounts are highlighted for two consecutive Mondays. During the night, that is, early morning hours (from 00:00 to 06:00 hours) on 22 December, negative electricity prices were realized on the EEX spot market, and the greatest negative amounts were realized in the third, fourth and fifth hour (Figures 7 and 8). In the daily electrical power system load diagram, which also presents the electricity consumption, the time period between midnight and 6 a.m. is the period of lowest energy consumption.

Tablica 3 – Satne cijene, EUR/MWh i volumeni trgovanja, MWh na spot tržištu EEX-a u razdoblju od 12.12.2008. do 18.12.2008. [5]
Table 3 – Hourly prices, EUR/MWh and trading volumes on the EEX spot market from 12 December 2008 to 18 December 2008 [5]

Sati / Hours	Cijena / Price	Dani / Days						
	Volmen / Volume	Pet / Fri	Sub / Sat	Ned / Sun	Pon / Mon	Uto / Tue	Sri / Wed	Čet / Thu
		12.12.2008.	13.12.2008.	14.12.2008.	15.12.2008.	16.12.2008.	17.12.2008.	18.12.2008.
00–01	EUR/MWh	44,76	41,21	20,15	38,85	46,12	46,17	46,02
	MWh	16 670,60	16 231,50	15 289,40	14 468,70	16 467,20	15 125,50	14 700,10
01–02	EUR/MWh	44,15	36,17	20,79	32,24	43,62	43,91	39,89
	MWh	16 165,10	16 582,20	15 155,90	14 726,60	16 488,20	15 545,30	15 041,10
02–03	EUR/MWh	41,84	36,29	19,47	33,61	42,39	40,08	38,99
	MWh	16 512,70	16 276,30	15 546,20	15 074,60	16 413,70	16 018,70	15 557,50
03–04	EUR/MWh	41,02	28,23	17,68	22,58	38,19	40,59	33,96
	MWh	16 479,90	16 485,10	15 743,10	15 422,60	17 095,40	16 136,30	15 865,60
04–05	EUR/MWh	40,94	26,95	17,65	30,27	36,24	40,55	31,25
	MWh	16 030,70	16 680,80	16 144,70	15 669,50	16 987,40	16 121,30	15 813,00
05–06	EUR/MWh	43,08	27,63	4,56	40,43	41,23	43,90	37,38
	MWh	16 379,00	16 157,70	15 873,20	14 915,40	16 420,00	16 173,70	15 795,00
06–07	EUR/MWh	64,90	27,11	2,06	58,16	55,21	53,08	46,46
	MWh	15 931,10	15 704,90	15 418,00	14 168,10	16 923,50	16 441,10	16 173,70
07–08	EUR/MWh	93,45	30,13	19,25	83,43	90,07	88,40	75,00
	MWh	18 950,50	15 737,10	15 700,50	19 920,90	20 114,70	19 600,60	19 156,00
08–09	EUR/MWh	90,06	41,22	20,17	81,93	75,03	87,30	70,05
	MWh	20 249,40	15 776,70	14 672,00	18 759,30	20 042,80	19 709,50	20 613,80
09–10	EUR/MWh	92,95	51,79	28,65	81,08	77,99	86,82	71,60
	MWh	20 202,20	15 294,00	14 489,10	18 508,20	19 987,40	20 156,40	20 236,60
10–11	EUR/MWh	93,32	53,71	36,68	82,58	85,02	85,93	75,05
	MWh	20 253,80	15 379,30	14 609,90	18 743,20	19 557,90	20 190,40	20 056,40
11–12	EUR/MWh	91,91	52,65	44,81	88,02	88,00	86,40	77,97
	MWh	19 947,60	14 948,20	14 767,20	18 899,30	19 256,80	20 131,30	19 809,80
12–13	EUR/MWh	90,29	48,90	43,50	88,02	82,33	83,70	72,07
	MWh	20 139,40	15 071,70	13 995,30	19 310,50	19 350,20	20 028,30	19 958,40
13–14	EUR/MWh	88,06	42,30	43,18	90,45	82,00	85,17	68,56
	MWh	20 194,20	15 203,40	14 721,30	19 569,60	19 614,50	19 901,70	20 322,00
14–15	EUR/MWh	82,08	38,42	38,97	84,53	79,92	79,80	67,48
	MWh	20 329,70	14 828,00	14 621,20	19 287,20	19 547,10	20 153,50	19 996,70
15–16	EUR/MWh	79,96	39,59	39,09	80,93	76,50	72,94	65,41
	MWh	20 534,70	14 884,80	14 291,00	19 229,90	19 545,50	20 086,30	19 908,40
16–17	EUR/MWh	89,20	47,98	45,92	87,31	80,05	82,52	77,07
	MWh	20 801,40	14 671,00	14 851,10	19 153,20	19 962,30	20 123,50	19 870,90
17–18	EUR/MWh	99,74	68,42	60,49	120,04	106,39	87,91	85,00
	MWh	20 931,20	15 318,80	15 261,20	19 234,60	19 688,00	19 865,80	19 915,40
18–19	EUR/MWh	85,07	64,01	62,85	104,36	100,00	80,07	72,06
	MWh	20 998,80	15 867,70	15 319,00	19 711,20	20 490,20	19 770,50	19 587,00
19–20	EUR/MWh	77,08	51,22	56,51	84,38	77,01	78,71	66,02
	MWh	20 991,90	15 485,30	14 843,60	19 085,80	19 934,20	19 594,70	19 969,30
20–21	EUR/MWh	72,01	46,57	50,03	78,02	80,12	75,05	64,85
	MWh	17 505,80	15 310,50	13 690,00	17 726,40	19 844,30	18 733,70	16 925,30
21–22	EUR/MWh	59,47	39,50	47,95	66,06	66,09	63,69	49,31
	MWh	17 467,80	15 425,50	13 568,50	16 336,00	18 631,30	17 045,30	16 820,60
22–23	EUR/MWh	54,31	39,52	50,71	61,40	63,01	53,53	44,09
	MWh	17 479,60	15 950,90	13 881,20	15 887,60	18 392,50	17 373,00	16 920,60
23-24	EUR/MWh	48,47	36,32	38,91	50,15	46,13	49,82	42,28
	MWh	16 231,80	15 679,80	13 699,80	15 653,50	17 858,00	16 197,30	15 429,50

Tablica 4 – Satne cijene, EUR/MWh i volumeni trgovanja, MWh na spot tržištu EEX-a u razdoblju od 19.12.2008. do 25.12.2008. [5]
Table 4 – Hourly prices, EUR/MWh and trading volumes, MWh on the EEX spot market from 19 December 2008 to 25 December 2008 [5]

Sati / Hours	Cijena / Price	Dani / Days						
	Volmen / Volume	Pet / Fri	Sub / Sat	Ned / Sun	Pon / Mon	Uto / Tue	Sri / Wed	Čet / Thu
		19.12.2008.	20.12.2008.	21.12.2008.	22.12.2008.	23.12.2008.	24.12.2008.	25.12.2008.
00–01	EUR/MWh	39,99	46,07	14,68	9,98	21,39	23,93	36,82
	MWh	14 085,50	14 575,50	15 230,30	14 911,50	14 642,40	16 073,50	15 948,20
01–02	EUR/MWh	34,90	35,05	0,08	–29,59	11,44	14,68	24,78
	MWh	14 189,60	15 067,40	14 892,80	15 713,60	14 907,30	15 425,40	16 276,20
02–03	EUR/MWh	36,11	25,14	–0,07	–101,52	6,92	18,88	22,58
	MWh	13 916,90	15 225,80	14 896,70	15 644,70	15 180,80	15 669,20	16 087,50
03–04	EUR/MWh	34,60	25,35	1,08	–101,52	2,33	15,82	14,98
	MWh	13 759,10	15 151,40	15 563,30	15 575,40	15 358,70	15 091,70	15 714,90
04–05	EUR/MWh	29,27	22,93	2,18	–101,50	5,08	11,91	10,62
	MWh	13 905,10	15 358,00	15 488,50	15 664,10	15 466,80	14 879,80	15 576,00
05–06	EUR/MWh	37,70	12,78	2,62	–9,98	21,09	11,03	11,51
	MWh	13 499,60	16 189,90	15 405,00	15 754,80	15 021,70	14 933,70	15 787,60
06–07	EUR/MWh	48,88	0,19	2,66	15,89	34,84	0,06	–20,01
	MWh	13 810,60	16 550,70	16 186,40	16 811,80	15 813,90	15 524,80	15 374,50
07–08	EUR/MWh	68,69	22,76	10,44	52,04	58,29	14,32	–0,01
	MWh	15 625,60	16 606,80	15 725,80	17 181,80	15 529,20	15 963,90	15 482,80
08–09	EUR/MWh	70,02	29,30	23,93	46,14	48,43	28,64	0,47
	MWh	19 041,50	16 502,30	15 082,80	21 679,00	19 246,50	20 715,40	20 365,70
09–10	EUR/MWh	70,01	43,38	45,59	46,71	51,30	43,12	13,09
	MWh	18 561,00	16 895,90	15 406,70	21 869,70	19 412,00	20 593,20	19 744,70
10–11	EUR/MWh	67,58	38,63	49,76	44,11	50,71	49,92	29,34
	MWh	18 269,80	16 350,70	15 750,20	21 161,50	19 077,60	20 228,60	20 535,70
11–12	EUR/MWh	69,84	48,10	66,90	50,72	55,21	48,85	43,19
	MWh	18 328,90	16 549,90	15 899,80	20 413,40	18 590,90	19 499,80	20 658,80
12–13	EUR/MWh	60,07	55,03	56,29	56,49	59,37	44,01	32,12
	MWh	19 223,10	16 780,20	15 540,00	20 936,30	18 883,50	19 770,90	20 670,10
13–14	EUR/MWh	54,82	49,81	48,71	51,94	55,98	36,90	24,09
	MWh	19 131,10	17 166,30	15 487,30	21 548,20	19 218,40	19 462,70	20 511,20
14–15	EUR/MWh	50,19	39,57	43,07	45,07	51,29	33,04	20,01
	MWh	18 811,40	17 042,50	15 938,70	21 465,00	19 718,20	19 407,20	21 190,80
15–16	EUR/MWh	48,71	39,02	41,27	43,25	46,87	24,63	12,46
	MWh	18 949,70	16 822,30	15 560,90	21 206,90	19 425,70	18 653,50	20 756,90
16–17	EUR/MWh	55,41	53,59	43,95	54,98	53,30	29,35	23,00
	MWh	18 652,00	16 653,20	15 320,00	20 208,10	18 751,60	18 440,00	20 931,70
17–18	EUR/MWh	75,02	62,55	60,06	71,68	75,75	49,98	36,84
	MWh	18 149,00	16 372,40	15 781,60	19 772,10	18 898,60	19 820,20	20 250,20
18–19	EUR/MWh	75,04	61,87	62,92	71,78	72,71	37,24	46,50
	MWh	18 881,30	16 212,30	15 270,60	19 712,80	19 150,60	19 849,80	20 252,60
19–20	EUR/MWh	60,05	60,06	59,98	64,10	68,64	29,71	43,95
	MWh	18 769,90	16 177,40	16 200,70	19 725,40	18 977,30	20 029,60	20 475,70
20–21	EUR/MWh	52,15	56,69	55,26	55,39	58,36	34,14	44,21
	MWh	14 248,10	16 632,70	16 326,30	15 069,80	16 248,60	15 623,20	15 509,40
21–22	EUR/MWh	45,06	41,09	44,98	44,75	44,92	36,98	37,13
	MWh	14 247,70	15 997,30	15 686,90	14 630,90	15 292,40	15 885,80	16 209,60
22–23	EUR/MWh	46,49	43,09	50,68	47,14	46,03	42,58	42,32
	MWh	13 936,50	16 005,90	15 579,90	14 292,30	15 868,80	16 205,30	16 600,30
23-24	EUR/MWh	36,96	21,45	23,09	36,82	41,51	37,65	31,20
	MWh	14 167,30	15 059,60	15 598,20	14 280,00	15 810,70	15 717,70	16 379,20

proizvodnje električne energije u odnosu na njenu smanjenu potrošnju najvjerojatnija je u ovom noćnom razdoblju. U skladu s tim ponuda električne energije u tim satima nešto je veća, pa je cijena manja nego u vrijeme dnevne potrošnje. Najveće cijene električne energije ostvarene su u vremenu povećane jutarnje i večernje potrošnje električne energije tj. u satima dnevnog vršnog opterećenja.

Temeljem arhive povijesnih podataka sa spot tržišta EEX-a tablica 5 predočava dane i sate kada su ostvarene negativne cijene električne energi-

The occurence of greater electricity production in relation to its reduced consumption is most probable in this time of night. In accordance with that, the offer of electricity in those hours is somewhat greater and therefore the price is lower than at daytime consumption. The greatest prices of electricity were realized at the time of increased morning and evening electricity consumption, that is, in the hours of the daily peak load.

Based on the historical data archive of the EEX spot market, Table 5 presents the days and the

je. U tablicama 4 i 5 zapaža se pojava negativne cijene obično u noćnim, odnosno ranim satima nedjeljnog ili blagdanskog jutra, ali ne tijekom cijele noći, već u jednom, dva ili najviše tri sata. Izuzetak predstavlja ponedjeljak 22. prosinca kada se negativna cijena zadržala tijekom većeg dijela noći.

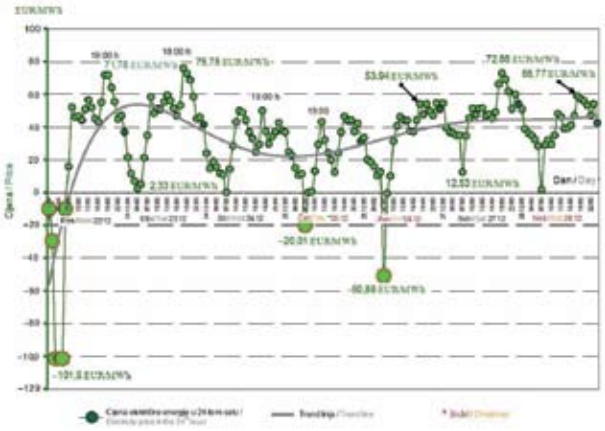
Na slici 5 prikazana je promjena satnih cijena električne energije u četvrtom tjednu prosinca 2008. godine. Posebno se ističu iznosi cijene (71,78 EUR/MWh, 75,75 EUR/MWh i 72,88 EUR/MWh) u razdoblju najveće potrošnje električne energije tijekom dana, što je uobičajeno za razdoblje vršnog opterećenja EES-a (tzv. vršna energija je najskuplja) te negativna cijena u noćnim/jutarnjim satima (–101,52 EUR/MWh). U četvrtom tjednu prosinca su bila dva blagdanska dana: četvrtak 25. prosinca i petak 26. prosinca (božićni blagdani) te nedjelja kao treći neradni dan. Poznato je da su u neradne i blagdanske dane potrošnja električne energije i opterećenje EES-a smanjeni. Posljedično su u te dane cijene i volumeni trgovanja na spot tržištu smanjeni. Osim već spomenute negativne cijene ostvarene u noćnim jutarnjim satima 22. prosinca, negativni iznosi cijene postignuti su i u jutarnjim satima, sedmom i osmom satu, 25. i 26. prosinca. Tijekom cijelog četvrtog tjedna cijene električne energije u ranim jutarnjim satima su male, a u nekim satima su vrlo blizu iznosa 0 EUR/MWh.

hours when negative electricity prices were realized. In Tables 4 and 5 occurrence of the negative price is observed, especially in night, that is, early Monday or Christmas morning hours, but not during the entire night, but in one, two or three hours maximum. En exception is Monday 22 December when the negative price lingered throughout most of the night.

Figure 5 shows a change in hourly prices of electricity in the fourth week of December 2008. Especially distinct are price amounts (71,78 EUR/MWh, 75,75 EUR/MWh and 72,88 EUR/MWh) in the period of highest energy consumption during the day, which is usual for the period of peak loading of the electrical power system (the so-called peak energy is most expensive) and the negative price in night/morning hours (–101,52 EUR/MWh). There were two holidays in the fourth week of December: Thursday, 25 December and Friday, 26 December (Christmas holidays) and Sunday as the third non-working day. It is a well-known fact that on non-working days and holidays energy consumption and electrical power system loading are reduced. This results in reduced prices and volumes of trading on the spot market. Besides the already mentioned negative price realized in early morning hours of 22 December, negative price amounts were also achieved in the morning hours, the seventh and the eighth hour of 25 and 26 December. Throughout the fourth week, the electricity prices in morning hours were small and in some hours very close to the amount of 0 EUR/MWh.

Tablica 5 – Podaci iz baze podataka EEX-a za dane i sate kada je ostvarena negativna cijena električne energije na spot tržištu [5]
Table 5 – Data from the EEX database for days and hours when the negative spot prices occured [5]

Dan / Day	Cijena električne energije / Electricity price, EUR/MWh									
Sati / Hours	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07–08	08–09	09–10
Petak (blagdan) / Friday (holiday) 26.12.2008.	33,45	19,99	18,62	15 86	10,37	12,45	–50,88	–0,61	10,02	31.32
Četvrtak (blagdan) / Thursday (holiday) 25.12.2008.	36,82	24,78	22,58	14,98	10,62	11,51	–20,01	–0,01	0,47	13,09
Ponedjeljak / Monday 22.12.2008.	–9,98	–29,59	–101,52	–101,52	–101,5	–9,98	15,89	52,04	46,14	46,71
Nedjelja / Sunday 21.12.2008.	14,68	0,08	–0,07	1,08	2,18	2,62	2,66	10,44	23,93	45,59
Nedjelja / Sunday 09.11.2008.	49,14	23,82	16,87	7,89	20,14	7,31	–2,16	0,02	9,46	25,59
Nedjelja / Sunday 05.10.2008.	50,79	25,57	1,12	0,05	0,02	–0,02	–1,03	–0,07	44,36	55,10



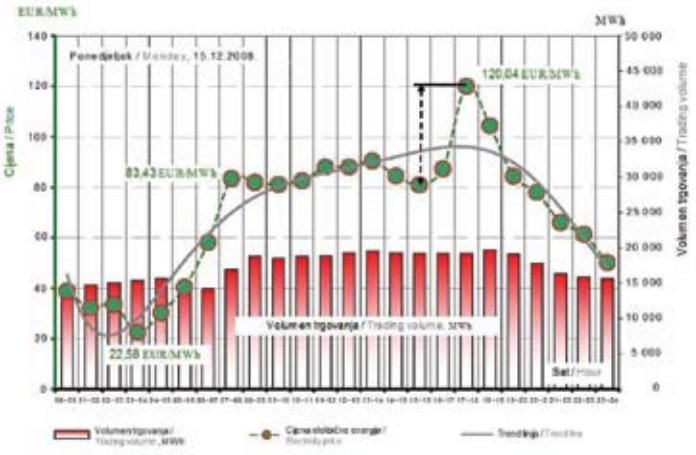
Slika 5 — Satne cijene električne energije na EEX-u tijekom četvrtog tjedna prosinca 2008. godine [5]
Figure 5 — Hourly electricity prices on EEX in the fourth week of December 2008 [5]

Slike 6 i 7 uspoređuju tijek promjene satnih cijena i volumena trgovanja za dva uzastopna ponedjeljka u prosincu. Slika 6 predočava uobičajenu promjenu satnih cijena u jednom danu koja je karakteristična po smanjenim iznosima tijekom noći i povećanim iznosima tijekom dana. Cijena električne energije najveća je u satima vršnog opterećenja EES-a, a najmanja od ponoći do ranih jutarnjih sati. Slika 7 prikazuje odstupanja od ove uobičajene situacije. Tijekom noći 22. prosinca cijena električne energije u razdoblju od 00:00 do 06:00 sati bila je u svim satima negativna. Najveći negativni iznos od **–101,52 EUR/MWh** postignut je u trećem i četvrtom satu, a zanemarivo manji od **–101,50 EUR/MWh** u petom satu. U ostalim satima tog ponedjeljka cijene su u prosjeku osjetno manje nego što su bile prethodnog ponedjeljka – mijenjale su se u opsegu između četrdesetak i sedamdesetak eura po megavatsatu. Porast cijene u satima vršnog opterećenja nije bio tako velik kao prethodnog ponedjeljka – najveća cijena (71,78 EUR/MWh) postignuta je u devetnaestom satu. Ipak, 22. prosinca ni dnevni volumen trgovanja niti volumen trgovanja po satima, posebice u prvih šest sati, nije bio toliko veći koliko bi se moglo očekivati s obzirom na vrlo povoljne cijene. Smanjena potrošnja u tom razdoblju nije mogla iskoristiti obilnu ponudu električne energije bez obzira ne vrlo prihvatljive cijene, odnosno činjenicu da se za kupnju/potrošnju dobivao novac.

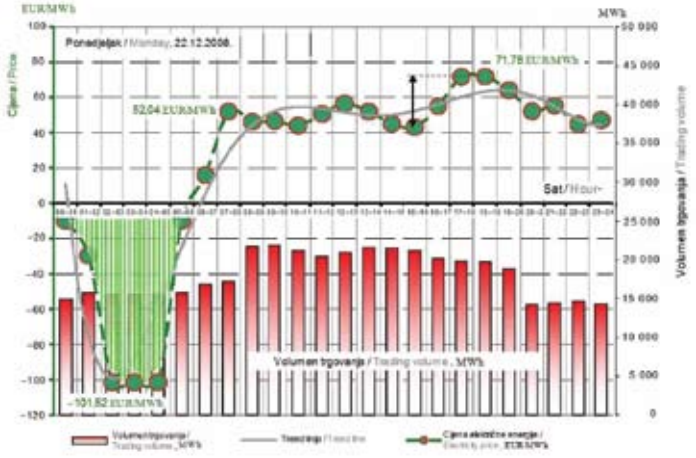
Prikažu li se zajedno na istom grafu satne cijene za dva razmatrana ponedjeljka u prosincu 2008. godine (slika 8) uočavaju se ipak određene sličnosti. Zajedničko je obilježje da su satne cijene električne energije tijekom noći barem dvostruko manje od dnevnih cijena. Zanemare li se za trenutak odstupanja u noćnim satima, trend promjene cijene u oba ponedjeljka je sličan – kao da je translatorno pomaknut po okomici.

Figures 6 and 7 compare the flow of changes of hourly prices and trading volumes for two consecutive Mondays in December. Figure 6 depicts the usual change of hourly prices in one day, which are characteristic for reduced amounts during the night and increased amounts during the day. Electricity price is at its highest in the hours of the electrical power system peak loading, and it is at its lowest from midnight to the early morning hours. Figure 7 shows deviations from this normal situation. During the night of 22 December, electricity price in the period between 00:00 and 06:00 was negative in all the hours. The highest negative amount of **–101,52 EUR/MWh** was achieved in the third and fourth hour and it is insignificantly lower than **–101,50 EUR/MWh** in the fifth hour. In the other hours of that Monday, prices were significantly lower than on the previous Monday – they fluctuated in the range between some forty and some seventy euros per megawathour. Increase of price in the peak loading hours was not as high as on the previous Monday – the highest price (71,78 EUR/MWh) was achieved in the nineteenth hour. Nevertheless, on 22 December, neither the daily trading volume nor the hourly trading volume, especially in the first six hours, were as high as could have been expected considering the very advantageous prices. Reduced consumption in that period could not use the abundant offer of electricity regardless of very favourable prices, that is, the fact that money was received for consumption/purchase.

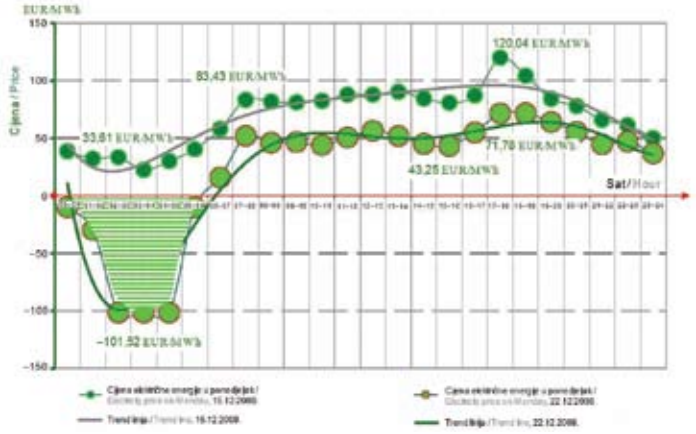
If on the same graph hourly prices are shown for two observed Mondays in December 2008 (Figure 8), certain similarities are nevertheless evident. A common feature is that hourly electricity prices during the night are at least two times as low as the daily prices. If we disregard the deviations in the night hours for a moment, the price change trend for both Mondays is similar- as if moved upon the perpendicular.



Slika 6 — Satne cijene električne energije i volumen trgovanja na EEX-u tijekom dana 15.12.2008. [5]
Figure 6 — Hourly electricity prices and the volume of trading on EEX on 15 December 2008 [5]



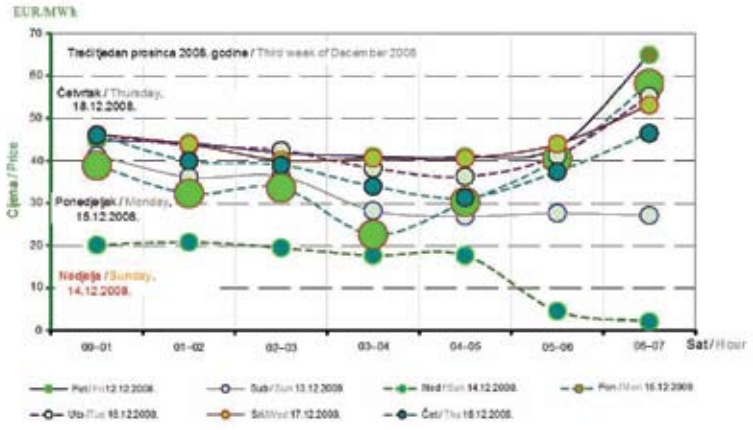
Slika 7 — Satne cijene električne energije i volumen trgovanja na EEX-u tijekom dana 22.12.2008. [5]
Figure 7 — Hourly electricity prices and the volume of trading on EEX on 22 December 2008 [5]



Slika 8 — Usporedba satnih cijena električne energije na EEX-u za dva uzastopna ponedjeljka u prosincu 2008. godine [5]
Figure 8 — Comparison of hourly electricity prices on EEX on two consecutive Mondays in December 2008 [5]

Slike 9 i 10 daju usporedni pregled satnih cijena u prvih sedam sati za sve dane u dva sedmodnevna razdoblja, od petka do idućeg četvrtka, krajem prosinca 2008. godine. Na taj se način može po danima pratiti opseg promjena cijene u određenom satu. U prvom razdoblju (trećem tjednu) primjetan je trend naglog porasta cijene u šestom i sedmom satu za sve radne dane. Slika 10 predočava veliko odstupanje cijena postignutih u ponedjeljak te manju razinu cijene i manje rasipanje za ostale dane u tjednu u odnosu na prethodni tjedan.

Figures 9 and 10 provide a review of hourly prices in the first seven hours for all the days in two seven-day periods, from Friday to next Thursday, at the end of December 2008. In this way, the range of price fluctuations within the particular hour can be followed according to days. In the first period (the third week), a sudden price increasing trend is noticeable in the sixth and seventh hour for all the working days. Figure 10 depicts a great deviation of prices achieved on Monday and a lower price level and lesser dissipation for other days of the week in relation to the previous week.



Slika 9 — Satne cijene električne energije na EEX-u tijekom trećeg tjedna prosinca 2008. godine u satima smanjene potrošnje [5]
Figure 9 — Hourly electricity prices on EEX during a low consumption period in the third week of December 2008 [5]

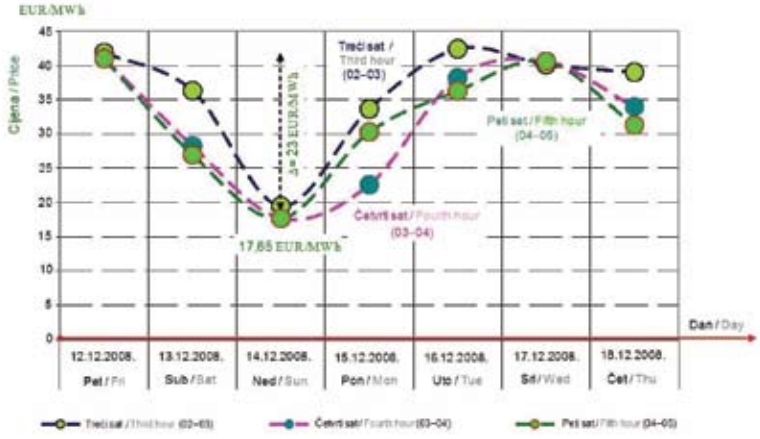
Slika 10 — Satne cijene električne energije na EEX-u tijekom četvrtog tjedna prosinca 2008. godine u satima smanjene potrošnje [5
Figure 10 — Hourly electricity prices during a low consumption period in the forth week of December 2008 [5]

Na slikama 11 i 12 izdvojene su, za sve dane u razmatranim sedmodnevnim razdobljima, cijene samo za treći, četvrti i peti sat u danu, tj. samo za sate kada su potrošnja električne energije i opterećenje EES-a obično najmanjeg iznosa. Gledajući radne dane u tjednu, u ranim jutarnjim satima prvog radnog dana u tjednu zadovoljen je

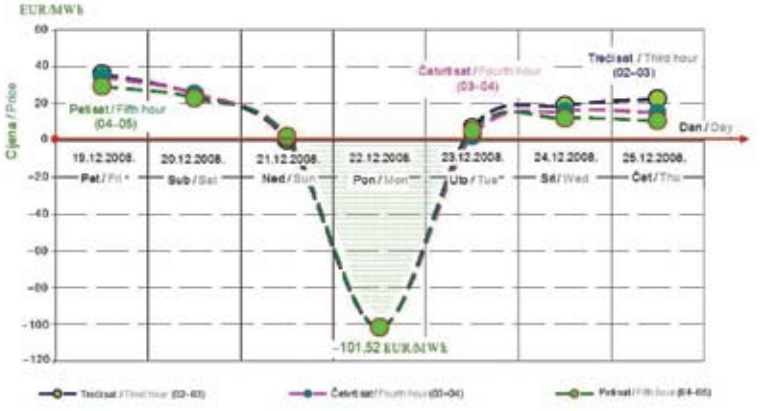
In Figures 11 and 12, for all the days in the observed seven-day periods, prices are singled out only for the third, fourth and fifth hour of the day, that is, only for those hours when the electricity consumption and the electrical power system loading are usually at their lowest. Looking at the working days of the week, in early morning hours

najveći broj uvjeta za postizanje najmanje cijene električne energije. Zaustavljeni tehničko-tehnološki postupci u tim su satima najčešće u režimu grijanja i održavanja stanja. Tek nešto kasnije bit će pokrenuti i tada će početi preuzimanje većih količina električne energije. Na slici 11 je vidljivo da je u trećem tjednu u svim razmatranim satima ostvaren propad cijene od oko 23 EUR/MWh u nedjelju. Cijene u trećem, četvrtom i petom satu u svim danima četvrtog tjedna gotovo da su jednake (slika 12) i manje su nego tjedan dana ranije. Najveća promjena cijena tj. propad veći od 100 EUR/MWh ostvaren je u ponedjeljak kada su cijene postigle praktično isti veliki negativni iznos. Također je vidljivo da su dan ranije (u nedjelju) i dan nakon (u utorak) u svim satima bile vrlo blizu 0 EUR/MWh.

of the first day of the week, most of the conditions for the achievement of the lowest electricity price are met. Technical-technological processes in those hours are non-operative and usually subjected to the heating and state maintenance regime. These will not be actuated until some later time and that is when the taking over of larger amounts of electricity will start. It is evident in Figure 11 that in the third week in all the observed hours a fall of the price of about 23 EUR/MWh was realized on Sunday. Prices in the third, fourth and fifth hour in all the days of the fourth week are almost equal (Figure 12) and lower than a week earlier. The greatest change of prices, that is, a fall greater than 100 EUR/MWh, was realized on Monday when the prices achieved the same high negative amount. It is also evident that a day earlier (on Sunday) and a day later (on Tuesday) these were very close to 0 EUR/MWh throughout the day.



Slika 11 — Cijene električne energije na EEX-u u satima smanjene potrošnje tijekom trećeg tjedna prosinca 2008. godine [5]
Figure 11 — Electricity price on EEX during a low consumption period in the third week of December 2008 [5]



Slika 12 — Cijene električne energije na EEX-u u satima smanjene potrošnje tijekom četvrtog tjedna prosinca 2008. godine [5]
Figure 12 — Electricity prices on EEX during a low consumption period in the fourth week of December 2008 [5]

3.3 Uzroci pojave negativne cijene na EEX-u

Negativna cijena na spot tržištu EEX-a u prosincu 2008. godine rezultat je velikog nerazmjera proizvodnje i potrošnje, odnosno ponude i potražnje električne energije. Nerazmjer može biti posljedica povećane ponude, smanjene potražnje ili i jednog i drugog istodobno. Krajem 2008. godine dogodilo se upravo to da se potražnja smanjila više nego što je uobičajeno, dok je ponuda istodobno bila značajno prevelika. Postavlja se pitanje što je uzrokovalo toliki nerazmjer ponude i potražnje. Zašto je potrošnja električne energije noću bila manja više nego obično te odakle tolika ponuda električne energije na tržištu? Uzroci koji su doveli do pojave negativne cijene različite su prirode, vremena nastanka, jačine i duljine djelovanja.

Prvi od razloga može se potražiti u financijskoj krizi koja je zahvatila gospodarstvo u posljednjem tromjesečju 2008. godine. Krajem godine veliki proizvodni pogoni automobilske industrije smanjivali su proizvodnju, ili čak prestajali s proizvodnjom, te već početkom prosinca poslali radnike na prinudni odmor od mjesec dana. Istodobno su se smanjile cijene metala na svjetskom tržištu, pa su tako, primjerice, proizvođači aluminija i talionice metalnog otpada smanjili svoju proizvodnju. Dakle, gospodarske djelatnosti koje su značajni potrošači električne energije u razmatranom su razdoblju značajno smanjile svoje potrebe za električnom energijom. Ova su se zbivanja vremenski podudarila s početkom godišnjeg odmora koji veliki broj radnika u zapadnoj i središnjoj Europi koristi u vrijeme božićnih blagdana. Upravo je ponedjeljak 22. prosinca bio dan početka dvotjednog godišnjeg odmora. Također, u razmatranom su razdoblju temperature zraka bile umjerene zimske temperature, zbog čega je potrošnja električne energije bila nešto manja od uobičajene za ovo doba godine. Ukupna dnevna potrošnja električne energije za područje trgovanja Njemačka/Austrija na EEX-u u ponedjeljak 22. prosinca bila je desetak posto manja u odnosu na prethodni ponedjeljak, a po satima je bila manja u rasponu od oko 4 % u drugom satu do oko 17 % u sedmom satu [14].

S druge strane, na području središnje Europe ostvarene su obilne padaline unutar tri tjedna krajem 2008. godine (negdje malo ranije, a negdje malo kasnije). One su pridonijele povećanju proizvodnje hidroelektrana te, posljedično, povećanoj ponudi električne energije na burzi po iznimno prihvatljivim cijenama. Nadalje, u ponedjeljak 22. prosinca, otprilike u isto vrijeme, ostvarena je, zbog povoljnog strujanja vjetra, proizvodnja vjetroelektrana u Njemačkoj veća od očekivane. Pritom treba imati na umu da in-

3.3 Causes of occurrence of the negative price at the EEX

The negative price on the EEX spot market in December 2008 is a result of great disproportion between production and consumption, that is, offer and demand of electricity. The disproportion may be a consequence of increased offer, reduced demand or both of these at the same time. At the end of 2008, what happened was exactly that the demand was reduced more than usual, while at the same time, the offer was much too high. The question arises as to what caused such disproportion between offer and demand. Why was the consumption of electricity at night lower than usual and where did such great offer of electricity on the market come from? The causes which led to the occurrence of the negative price are of various natures, times of occurrence, intensity and duration of impact.

The first reason could have originated from the financial crisis which had attacked the economy in the last trimester of the year 2008. At the end of the year, large production plants of the automobile industry were reducing their production, or even stopping it, and, as early as at the beginning of December, sending their workers on one-month forced vacations. Prices of metals on the world market decreased at the same time, and thus, for example, aluminium producers and metal waste melting foundries reduced their production. So, commercial businesses which are significant consumers of electricity greatly reduced their needs for electricity in the observed period. The time when these events happened coincided with the beginning of annual vacations used by many workers in western and middle Europe in the period of Christmas holidays. Monday, 22 December was exactly the day when the two-week annual vacations started. Moreover, in the observed period, air temperatures were moderate winter temperatures, because of which the energy consumption was somewhat lower than the usual for this period of the year. Total daily consumption of electricity for the EEX market area of Germany/Austria on Monday, 22 December was by some ten percent lower in relation to the previous Monday, and, as regards the hours, it was lower in the range of about 4 % in the second hour up to about 17 % in the seventh hour [14].

On the other hand, in the area of middle Europe, abundant rainfall occurred within the three last weeks of the year 2008 (in some places somewhat earlier, in other, somewhat later). These contributed to increased production of hydroelectric power plants and, consequentially, to an increased offer of electricity at exceptionally acceptable prices. Furthermore, on Monday 22 December, at about the same time, wind power plants in Germany realized a production higher than expected due to favourable wind circulation. What should be born in mind thereat is that the installed power of those wind power plants

stalirana snaga tih vjetroelektrana nadmašuje 23 GW te da su njihovu proizvedenu energiju tamošnji operatori prijenosnog sustava obvezni preuzeti, zbog uspostavljenog sustava poticanja proizvodnje električne energije iz obnovljivih izvora energije. Dakle, raspolagalo se s viškovima električne energije iz hidroelektrana, čija je energija jeftinija, te iz vjetroelektrana čija se energija u potpunosti preuzima.

U takvoj situaciji neke se termoelektrane moglo staviti u rezervu ili kratkoročno isključiti iz pogona na tjedan dana, čime bi se jednostavnije uravnotežio višak električne energije. Budući da podaci i informacije o tome nisu dostupni, ovdje se pretpostavlja kako je zaključeno da takva mjera potencijalno može imati i negativne učinke po sigurnost sustava. Naime, poznato je da termoelektrane i nuklearne elektrane uz radnu energiju proizvode i dostatnu jalovu energiju čime održavaju stabilnim napone u EES-u i značajno podržavaju stabilnost sustava. Trajan rad termoelektrana i nuklearnih elektrana jamči održavanje naponske i dinamičke stabilnosti povezanih europskih EES-a. One svaki EES čine krutim u odnosu na sve vrste kratkotrajnih prolaznih poremećaja. Može se pretpostaviti da je tijekom noćnih sati, kada su se pojavili viškovi električne energije, jednostavnije i isplativije bilo platiti kupcu nešto više od 100 EUR/MWh i prepustiti energiju, nego dovesti sigurnost sustava u potencijalnu opasnost pojave poremećaja koji bi se teže sanirao. Također, zbog tehničkih karakteristika i troškova zaustavljanja te ponovnog pokretanja proizvodnje u termoelektranama ponekad je ekonomski opravdano ostaviti elektranu u radu i istodobno za to platiti. Dakle, neke termoelektrane vjerojatno nisu smanjivale ili zaustavljale svoju proizvodnju što je također pridonijelo stvaranju viška ponude. Ipak, pretpostavka je da se, kada je i gdje je bilo moguće, smanjivala proizvodnja skupljih termoelektrana (s većim troškovima proizvodnje električne energije) i nadomještavala kupovinom proizvodnje iz hidroelektrana.

Za bolji i cjelovitiji uvid bilo bi zanimljivo vidjeti detalje ponude i potražnje na spot tržištu EEX-a u razmatranom razdoblju, kao i detaljnije podatke o potrošnji i proizvodnji električne energije na području zapadne i središnje Europe u to vrijeme, ali ovi podaci nisu javno dostupni. Usprkos tomu, na temelju svega dosad navedenog može se zaključiti da se u razmatranom razdoblju zbog povećane proizvodnje u hidroelektranama i vjetroelektranama, unatoč vrlo vjerojatnom smanjenju proizvodnje u termoelektranama, raspolagalo značajnim viškovima električne energije koji su ponuđeni na spot tržištu. Povećana ponuda uz istodobno smanjenu potražnju uzrokovala je iz dana u dan padanje cijene elek-

exceeds 23 GW and that the energy they produce has to be taken over by the yonder transmission system operators because of the established system of stimulation of electricity production from renewable sources of energy. Therefore, surpluses of electricity from hydroelectric power plants, which generate cheaper energy, were available as well as those from wind power plants the energy of which is taken over in full.

In such a situation, some thermal power plants could have been put in stand-by mode or turned off for a week which would have made it easier to balance the surplus of electricity. As data and information thereon are not available, the assumption here is that the conclusion was made that such a measure could also possibly negatively affect the system safety. Namely, it is well-known that, together with active power, thermal power plants and nuclear plants produce sufficient reactive power which serves to maintain the stability of the voltages of the electrical power system and significantly support the system stability. Continuous operation of thermal power plants and nuclear plants guarantees the maintenance of voltage and dynamic stability of connected European electrical power systems. These plants make each electrical power system solid against all kinds of short-term transient disruptions. It can be assumed that during the night hours, when electricity surpluses occurred, it was cheaper and more cost-effective to pay the buyer something more than 100 EUR/MWh and let down the energy than to put the system safety at possible risk from occurrence of disruptions which would be more difficult to resolve. Also, due to technical characteristics and costs of stopping and re-actuating the production in thermal power plants, it is sometimes economically justified to leave the power plant in operation and pay for it at the same time. Therefore, some of the power plants probably did not decrease or stop their productions which also contributed to the generation of excessive offer. However, the assumption is that, when and where it was possible, the production of more expensive thermal plants (with higher electricity production costs) decreased and was substituted with purchase of production from the hydroelectric power plants.

For a better and fuller insight, it would be interesting to see offer and demand details on the EEX spot market in the observed period, as well as more detailed data on the consumption and production of electricity in the area of western and middle Europe at that time, but these data are not publicly available. In spite of that, based on everything mentioned so far, it can be concluded that in the observed period, due to an increased production of hydroelectric power plants and wind power plants, in spite of a probable decrease of production in thermal power plants, significant surpluses of electricity were available which were offered on the spot market. Increased offer with

trične energije na spot tržištu, što je u konačnici rezultiralo postizanjem velikog negativnog iznosa u noćnim satima 22. prosinca.

4 PRILIKE U HRVATSKOM EES-u KRAJEM 2008. GODINE

4.1 Migracija proizvodnje električne energije u hrvatskom EES-u

Potrebe za električnom energijom u hrvatskom EES-u uglavnom se podmiruju iz tri vrste izvora: proizvodnjom u termoelektranama, proizvodnjom u hidroelektranama te kupovinom električne energije izvan granica Hrvatske. Na godišnjoj razini termoelektrane najvećim dijelom sudjeluju u pokrivanju potrošnje električne energije u Hrvatskoj. Nešto manji udio ostvaruju hidroelektrane, a potom slijede i ostali izvori. Nezanemariv dio ukupnih potreba pokriva se uvozom. Značajno povećanje jednog od načina proizvodnje istodobno rezultira potrebom za smanjenjem proizvodnje drugih skupina izvora. U razdoblju povoljnih hidroloških prilika povećavaju se dotoci, a povećanjem dotoka povećava se količina proizvedene električne energije u hidroelektranama na račun smanjenja proizvodnje u termoelektranama. Omjer proizvodnje električne energije iz termoelektrana i hidroelektrana se neprekidno mijenja na razini sata, dana i mjeseca.

Uobičajeni tokovi snaga u hrvatskom EES-u najčešće imaju smjer od sjevera prema jugu. Krajem 2008. godine, u studenom i prosincu, udio termoelektrana u pokrivanju dnevnih potreba za električnom energijom kretao se u opsegu od 34 % do 55 %dnevne potrošnje električne energije Hrvatske, dok se udio hidroelektrana mijenjao od 18 % do 58 %. U pojedinim danima satni udjeli elektrana u podmirivanju satne potrošnje električne energije mijenjali su se i u većem opsegu od ovdje navedenih iznosa. Povećanjem padalina i dotoka koji su bujičnog karaktera struktura proizvodnje električne energije i smjer tokova energije mijenjao se postupno i neprekidno iz dana u dan. Značajnim povećanjem proizvodnje hidroelektrana smještenih u priobalnom dijelu Hrvatske tok električne energije promijenio je smjer tako da se energija prenosila od juga ka sjeveru. Povećana proizvodnja hidroelektrana potisnula je rad termoelektrana, od kojih su neke prestale s radom. U radu su ostale samo termoelektrane koje sustav čine otpornim na prolazne poremećaje, odnosno koje su važne za stabilnost EES-a. Dakle, zbog obilatih i dugotrajnih povećanja dotoka težište proizvodnje električne energije utemeljeno u Hrvatskoj na velikim termoelektranama u kontinentalnom dijelu zemlje te Istri i Primorju pomaklo se na jug.

a simultaneously reduced demand caused the spot market electricity price to fall day after day, which in the end resulted in the achievement of high negative amounts in the night hours of 22 December.

4 CIRCUMSTANCES IN THE CROATIAN ELECTRICAL POWER SYSTEM AT THE END OF 2008

4.1 Migration of electricity production in the Croatian electrical power system

The needs for electricity of the Croatian electrical power system are mostly settled from three sources: production by thermal power plants, production by hydroelectric power plants and purchase of electricity from outside the borders of Croatia. At the annual level, thermal power plants mostly participate in covering the consumption of electricity in Croatia. A somewhat lesser share is realized by hydroelectric plants and then the other sources follow. A significant part of daily needs is covered by import. A significant increase of one type of production results in the need for a reduction of production of the other source groups. In the period of favourable hydrological circumstances inflows increase, and the increase of inflows increases the quantity of produced electricity in hydroelectric power plants to the detriment of reduction of production in thermal power plants. The ratio of electricity production from thermal power plants and hydroelectric power plants changes constantly on the level of an hour, a day and a month.

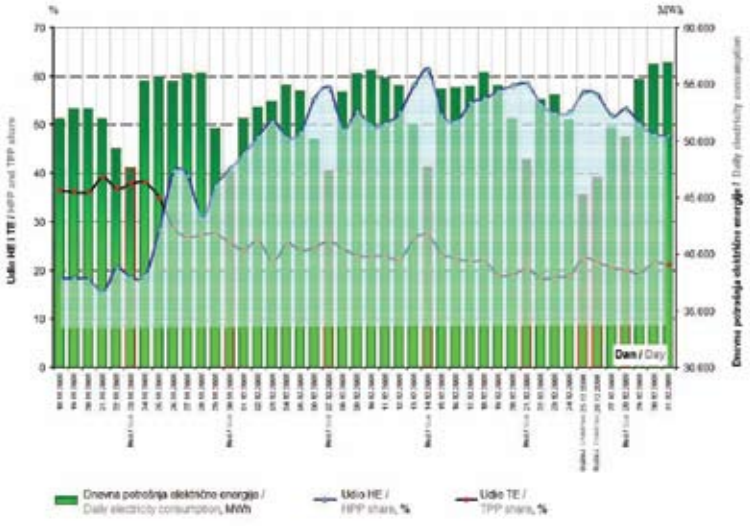
The usual power flows in the Croatian electrical power system are most often directed north to south. At the end of 2008, in November and December, the share of thermal power plants in covering daily needs for electricity fluctuated in the range from 34 % to 55 % of the daily electricity consumption in Croatia, while the share of hydroelectric power plants ranged from 18 % to 58 %. In particular days, hourly shares of power plants in covering hourly electricity consumption changed to the extent even greater than the amounts stated here. Owing to increased rainfall and inflows of torrent character, the structure of electricity production and the direction of power flows changed gradually and constantly day by day. By significantly increasing the production of hydroelectric power plants located in the coastal area of Croatia, the electricity flow changed its direction so that the power was transferred from south to north. Increased production of hydroelectric power plants suppressed the operation of thermal power plants of which some discontinued their operations. Only the thermal power plants which make the system resistant to transient disruptions, that is, those of importance for the stability of the electrical power system re-

Ovom procesu promjene tokova energije pridonijele su svojim povećanim radom i velike hidroelektrane u Bosni i Hercegovini, koje se nalaze u zaleđu hrvatskog EES-a. Veliki dio svoje proizvodnje ove elektrane u pravilu utiskuju u južni dio hrvatskog EES-a, čime pridonose tokovima energije od juga prema sjeveru. Pretpostavka je da se sličan proces promjene strukture proizvodnje električne energije događao u zapadnoj i središnjoj Europi budući da su krajem 2008. godine i tamo ostvarene značajne padaline i povoljni hidrološki uvjeti. Detaljni podaci kojima bi se to potvrdilo nisu javno dostupni.

Slika 13 predočava promjenu strukture proizvodnje električne energije u hrvatskom EES-u u studenom i prosincu 2008. godine – prevladavajuću proizvodnju u termoelektranama zamijenila je proizvodnja u hidroelektranama. Na slici je proizvodnja elektrana prikazana udjelom, % u pokrivanju satne potrošnje električne energije u Hrvatskoj. Vrijedi napomenuti da se zbog obilnih dotoka uz povećanu proizvodnju hidroelektrana istodobno ostvarilo intenzivno punjenje svih hrvatskih akumulacija.

mained operative. Therefore, due to abundant and long-term increases of inflows, the centre of gravity of electricity production established in Croatia on large thermal power plants in the continental part of the country and in Istria and Primorje moved southwards. Increased operation of large hydroelectric power plants in Bosnia and Herzegovina located in the background of the Croatian electrical power system also contributed to this process of changed power flows. These power plants send a large share of their production in the southern part of the Croatian electrical power system, by which they contribute to power flows from south to north. The assumption is that a similar process of change of electricity production structure happened in western and middle Europe because at the end of 2008 significant rainfall and favourable hydrological conditions were realized there as well. Detailed data which would corroborate this are not publicly available.

Figure 13 presents a change of the electricity production structure in the Croatian electrical power system in November and December 2008 – the prevailing production in thermal power plants was substituted by production in hydroelectric power plants. The Figure represents the share of production of power plants of % in covering hourly electricity consumption in Croatia. It is worthwhile to mention that because of abundant flows with increased hydrothermal plants production, intensive filing of all Croatian power plant reservoirs was realized.



Slika 13 — Učešće proizvodnje hidroelektrana i termoelektrana u podmirivanju potrošnje električne energije u Hrvatskoj krajem 2008. godine

Figure 13 — Participation of hydropower plants and thermal power plants in daily consumption of Croatia at the end of year 2008

Ista su događanja podrobnije predočena primjerima koji predstavljaju hidrološki različita zimska

The same events are presented in more detail by virtue of examples which represent hydrologically

razdoblja. Za primjere su odabrani dan 23. studenog 2008. godine koji predstavlja uobičajeno zimsko relativno sušno razdoblje, te dan 14. prosinca 2008. godine kao primjer izrazito povoljne hidrologije kad je proizvodnja hidroelektrana značajno povećana. Za razdoblje sredine mjeseca studenog može se reći da je uobičajeno razdoblje bez velikih dotoka. Nakon 23. studenog 2008. godine do kraja godine bilo je hidrološki povoljno zimsko razdoblje s obilnim dotocima vode u trajnom porastu, što već dugo nije zabilježeno. U zimskom relativno sušnom razdoblju većinu potrošnje podmirivala je proizvodnja u termoelektranama (na dnevnoj razini oko 55 %), manji dio podmirivao se proizvodnjom u hidroelektranama (na dnevnoj razini oko 21 %), dok je preostala potrošnja pokrivena vrlo malim udjelom ostalih proizvodnih postrojenja i uglavnom uvozom električne energije. U razdoblju povoljne hidrologije struktura proizvodnje u hrvatskom EES-u bila je bitno različita, odnosno upravo obrnuta. Većina se potrošnje podmirivala iz hidroelektrana (na dnevnoj razini oko 58 %), a manji dio iz termoelektrana (na dnevnoj razini oko 25 %). Kao i u prethodnom primjeru, preostala potrošnja pokrivena je uvozom električne energije i vrlo mali dio proizvodnjom u ostalim proizvodnim postrojenjima. Iako se tijekom prosinca cijena električne energije u Europi smanjivala, veći uvoz električne energije u Hrvatsku za potrebe domaće potrošnje nije ostvaren zbog velike količine raspoložive energije u hidroelektranama hrvatskog EES-a.

Slike 14 i 15 su prikazi trenutačne bilance snaga dobiveni iz programa Dispečerska analiza mreže (DAM) u kojem se podaci i grafički prikazi osvježavaju s vrlo velikom učestalošću. Budući da je relativno teško uhvatiti isti trenutak u različitim danima, prikazane su prilike u EES-u u različitim trenucima unutar istog sata. U ovom radu to nije predstavljalo poteškoću, jer su razmatrani iznosi tržišne cijene i volumena trgovanja na razini sata. Slikama su prikazane bilance tokova snaga na svim granicama hrvatskog EES-a te tokovi snaga na nekim značajnijim dalekovodima 400 kV i 200 kV koji predstavljaju važne povezne pravce u regiji jugoistočne Europe. Obje slike prikazuju bilance snaga tijekom šestog sata ujutro u nedjelju (23. studenog 2008. i 14. prosinca 2008. godine). Opterećenje je bilo približno istog iznosa (oko 1 510 MWh/h i 1 513 MWh/h), ali se proizvodnja u hidroelektranama i termoelektranama bitno razlikovala (ukupno 752 MWh i 1 222 MWh). Usporede li se bilance po granicama može se primijetiti povećanje uvoza iz Mađarske (oko 150 MW) i Bosne i Hercegovine (oko 90 MW) te značajno povećanje izvoza u Sloveniju (oko 630 MW). Slični su iznosi ostvareni tijekom cijele noći razmatranog vlažnog zimskog dana. Slične prilike u prijenosnoj

different winter periods. The following are chosen as examples: 23 November 2008, which represents the usual, relatively dry, winter season, and 14 December 2008 as an example of extremely favourable hydrology when the production of hydroelectric power plants increased significantly. For the period of the middle of November it can be said that it is the usual period without great inflows. The period between 23 November 2008 and the end of the year was a hydrologically favourable winter period with abundant and constantly increasing water inflows such as had not been recorded in a long time. In the relatively dry winter season, most of the consumption was settled by production of thermal power plants (at a daily level of about 55 %), a smaller share was settled by production of hydroelectric power plants (at a daily level of about 21 %), while the remaining consumption was covered by a very low share of the other production facilities and mainly by import of electricity. In the period of favourable hydrology, the production structure in the Croatian electrical power system was significantly different, that is, exactly the opposite. Most of the consumption was settled from hydroelectric plants (at a daily basis of about 58 %), and a smaller share from thermal power plants (at a daily basis of about 25 %). Just as in the previous example, the remaining consumption was covered by import of electricity and a very small share by production in the other production plants. Although during December the electricity price in Europe was reduced, a greater import of electricity into Croatia, for the needs of domestic consumption, was not realized due to large amounts of available power in the hydroelectric power plants of the Croatian electrical power system.

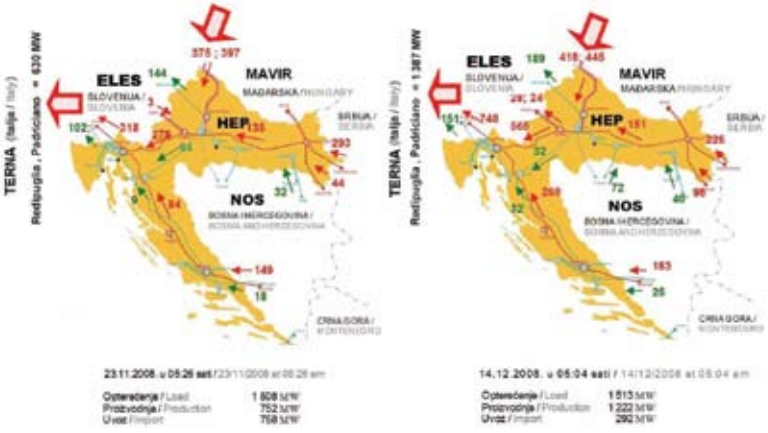
Figures 14 and 15 are presentations of the current power balances obtained by the Dispatcher Network Analysis (DAM) program in which data and graphic figures are updated at a very frequent rate. As the same moment in different days can hardly be captured, circumstances in the electrical power system in different moments of the same hour are shown. This did not create a problem in this work because market price amounts and trade volumes were considered at the level of an hour. The figures show power flow balances at all the borders of the electrical power system, and power flows on certain significant transmission lines 400 kV and 200 kV which represent important connection routes in the south-eastern Europe region. Both figures show power balances during the sixth hour of Sunday morning (23 November 2008 and 14 December 2008). Load was approximately of the same amount (about 1 510 MWh/h and about 1 513 MWh/h), but the production at hydroelectric power plants and thermal power plants varied significantly (total of 752 MWh and about 1 222 MWh). If balances at the borders are compared, an increase of import from Hungary is evident (about 150 MW) and from Bosnia and Herzegovina (about 90 MW), as well as significant increase of export into Slovenia (about 630 MW).

mreži 400 kV i 220 kV hrvatskog EES-a za odabrana hidrološki različita razdoblja prikazane su slikom 16.

Similar amounts were realized throughout the night of the observed winter day. Similar circumstances in the 400 kV and 220 kV transmission network and in the Croatian electrical power system for the chosen, hydrologically different, periods are shown in Figure 16.

Slika 14 — Tokovi snaga u zimskom sušnom razdoblju (studeni 2008. godine) [15]
Figure 14 — Power flows during dry winter period (November 2008) [15]

Slika 15 — Tokovi snaga u razdoblju povećanih dotoka zimi (prosinac 2008. godine) [15]
Figure 15 — Power flows during favourable hydrology in winter period (December 2008) [15]



Slika 16 — Tokovi snaga u prijenosnoj mreži 400 kV i 220 kV hrvatskog EES-a u dva zimska hidrološki različita razdoblja [15], [16]
Figure 16 — Power flows in 400 kV and 220 kV transmission network of Croatian power system for different hydrology in winter period [15], [16]

4.2 Promjena tokova snaga u hrvatskom EES-u

Operator prijenosnog sustava po svojoj osnovnoj zadaći nema dodira s cijenama električne energije na spot tržištu. Trgovački tokovi električne energije u pravilu se ne podudaraju sa stvarnim fizičkim tokovima električne energije, ali promjene u trgovanju električnom energijom mogu rezultirati bitnim promjenama fizičkih tokova snaga. Stoga operator prijenosnog sustava, odnosno voditelj sustava može zamijetiti značajnije promjene cijena posredno kroz neobične fizičke tokove snaga. Takav je učinak povremeno zamijećen u hrvatskom EES-u tijekom tri tjedna prosinca 2008. godine, kada je zamjetna promjena tokova snaga bila vidljiva noću od 00:00 do 06:00 sati.

Promjenu tokova snaga u EES-u prvenstveno uzrokuje promjena proizvodnje, ali i značajna razmjena električne energije sa susjednim EES-ima. Kao što je u radu već navedeno, u prosincu 2008. godine cijena električne energije bila je višestruko povoljnija nego cijena električne energije koju bi proizvele domaće termoelektrane u nekim europskim zemljama. Zato su tranziti električne energije u Europi promijenili iznos i smjer tako da je energija iz dotocima bogatih regija, gdje su smještene velike hidroelektrane, imala smjer prema regijama s velikom potrošnjom električne energije.

Krajem 2008. godine u hrvatskom EES-u zapažene su dvije značajne promjene tokova snaga. Prvo se zapažanje odnosi na promjenu iznosa i smjera tokova snaga u hrvatskom EES-u uzrokovanu povećanjem i preraspodjelom proizvodnje. Zbog trajno povećane proizvodnje u najvećim hidroelektranama na jugu hrvatskog EES-a te u Bosni i Hercegovini kao njegovom energetskom zaleđu, zbog smanjenog uvoza električne energije za potrebe domaće potrošnje te prestanka rada nekih termoelektrana, uobičajeni smjer toka energije od sjevera prema jugu promijenjen je u smjer od juga prema sjeveru. Drugo se zapažanje odnosi na promjene tranzitiranja električne energije preko hrvatskog EES-a. Tokovi snaga iz Mađarske preko hrvatskog EES-a u smjeru Italije su povećani osobito u noćnim satima. Do ove pojave došlo je zbog malih cijena električne energije u središnjoj i zapadnoj Europi. Električna energija ponuđena na tržištu po povoljnim cijenama kupljena je i uvezena u Italiju kao zamjena za skuplju domaću proizvodnju u termoelektranama. Uvezena energija također je korištena za rad crpnih elektrana čija instalirana snaga u Italiji prelazi 7 600 MW. Na taj se način jeftina električna energija pohranjivala u akumulacijama za kasniju uporabu kada se, primjerice, tržišne cijene povećaju.

4.2 Change of power flows in the Croatian electrical power system

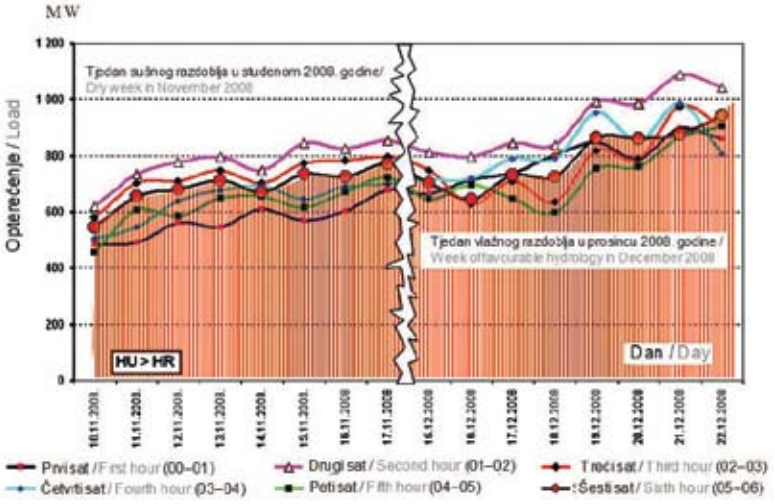
The basic task of the transmission system operator does not put him in contact with electricity prices on the spot market. Electricity trade routes generally do not coincide with actual physical electricity flows, but changes in electricity trading may result in significant changes of physical power flows. Therefore, the transmission system operator, that is, the system manager, can notice significant price variations indirectly through unusual physical power flows. Such effect was occasionally noticed in the Croatian electrical power system during the three weeks of December 2008 when a noticeable change in power flows was evident at night from 00:00 to 06:00.

The change in power flows of the electrical power system is primarily caused by a change of production, but also by a significant exchange of electricity with the neighbouring electrical power systems. As has already been mentioned in the work, in December 2008, the electricity price was several times more favourable than the price of electricity which would have been produced by domestic thermal power plants in certain European countries. Therefore, the electricity transits in Europe changed their directions and amounts so that the energy from the inflow-rich regions, where large hydroelectric power plants are located, was directed towards the regions with high electricity consumption.

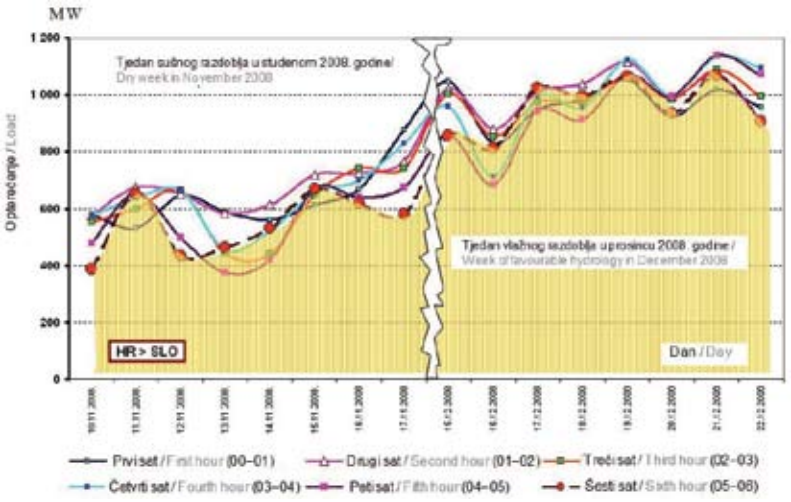
At the end of 2008, two significant power flow changes were noticed in the Croatian electrical power system. The first observation relates to the change of power flow amounts and directions in the Croatian electrical power system caused by increase and redistribution of production. Due to a permanent increase of production in the largest hydroelectric power plants in the south of the Croatian electrical power system and in Bosnia and Herzegovina as its energy background, due to a reduced import of electricity for the needs of domestic production and the termination of operation of certain thermal power plants, the usual direction of the power flow from north to south was changed to the direction from south to north. The second observation relates to changes in transits of electricity through the Croatian electrical power system. Power flows from Hungary through the Croatian electrical power system towards Italy were increased, especially in night hours. This occurrence was caused by low electricity prices in middle and western Europe. The electricity offered on the market at favourable prices was bought and imported into Italy as substitution for the more expensive domestic production in thermal power plants. The imported energy was also used for the operation of pumping power plants whose installed power in Italy exceeds 7 600 MW. In such a way, cheap electricity was stored in reservoirs for later use, when, for example, market prices increase.

Dakle, u razmatranom se razdoblju dogodilo značajno povećanje proizvodnje električne energije na jugu hrvatskog EES-a koja je odlazila u pravcu sjevera i najvećih potrošača te povećani ulaz električne energije iz smjera Bosne i Hercegovine i Mađarske u Hrvatsku. Najveći dio ove energije, odnosno tokova snaga, uočen je na granici Hrvatske i Slovenije te dalje na granici Slovenije i Italije. Slike 17, 18 i 19 prikazuju opterećenja dalekovoda na granicama Mađarske i Hrvatske, Hrvatske i Slovenije te Slovenije i Italije u noćnim satima (od 00:00 do 06:00 sati). Ovdje su u istom grafičkom prikazu predočena opterećenja za sušno razdoblje sredinom studenog 2008. godine te za vlažno razdoblje od 15. do 22. prosinca 2008. godine. Grafički prikazi stvoreni su temeljem podataka iz sustava Vulcanus [16]. Slike predočavaju trend porasta prekograničnih tokova u smjeru Italije koji se podudaraju s pojavom male cijene električne energije na spot tržištu koja je razmatrana u ovom radu. Dio tokova snaga na slovensko-talijanskoj granici zatvorio se kroz mađarski, hrvatski i slovenski EES, dok se dio zatvorio kroz austrijski i slovenski EES. Na sve tri slike površinom ispod krivulje predstavljen je prekogranični tok električne energije u šestom satu (od 05:00 do 06:00 sati).

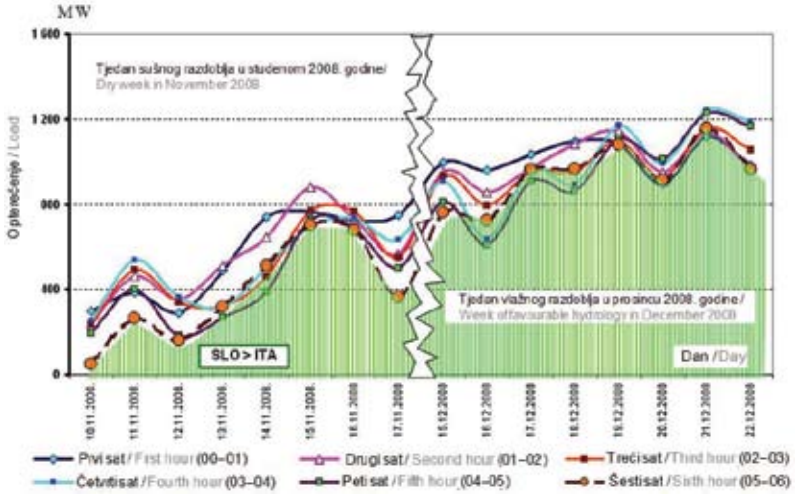
So, in the observed period, a significant increase of electricity production occurred in the south of the Croatian electrical power system which went towards north and the largest users, and an increased input of electricity from Bosnia and Herzegovina and Hungary into Croatia. The largest share of this power, that is, of power flows, was noticed at the border between Croatia and Slovenia and farther at the border of Slovenia and Italy. Figures 17, 18 and 19 show transmission lines loads at the borders between Hungary and Croatia, Croatia and Slovenia, Slovenia and Italy in the night hours (from 00:00 to 06:00). Here, in the same graphic presentation, loads are shown for the dry period at the middle of November 2008, and for the wet period from 15 to 22 December 2008. Graphic presentations are created according to the data from the Vulcanus system [16]. The figures depict the growth trend of cross-border flows towards Italy which coincide with the occurrence of low electricity prices on the spot market which has been elaborated in this work. Part of the power flows at the Slovenian-Italian border was closed through the Hungarian, Croatian and Slovenian electrical power system, while a part was closed through the Austrian and Slovenian electrical power system. In all the three figures, the surface under the curve shows the cross-border flow of electricity in the sixth hour (from 05:00 to 06:00).



Slika 17 — Prekogranični tokovi snaga iz Mađarske u Hrvatsku tijekom noći u sušnom i vlažnom zimskom razdoblju 2008. godine [16]
Figure 17 — Cross-border power flows from Hungary to Croatia during night for dry and wet winter period in year 2008 [16]



Slika 18 — Prekogranični tokovi snaga iz Hrvatske u Sloveniju tijekom noći u sušnom i vlažnom zimskom razdoblju 2008. godine [16]
Figure 18 — Cross-border power flows from Croatia to Slovenia during night for dry and wet winter period in year 2008 [16]



Slika 19 — Prekogranični tokovi električne energije iz Sloveniju u Italiju tijekom noći u sušnom i vlažnom zimskom razdoblju 2008. godine [16]
Figure 19 — Cross-border power flows from Slovenia to Italy during night for dry and wet winter period in year 2008 [16]

5 ZAKLJUČAK

Negativna cijena na spot tržištu EEX-a rezultat je zajedničkog djelovanja više čimbenika koji su se istodobno dogodili krajem 2008. godine. Kraj godine obično nije razdoblje pojačavanja gospodarske djelatnosti, početka novog proizvodnog ciklusa i sl., već je to razdoblje privođenja poslova kraju te ulaska u blagdansko raspoloženje i vrijeme odmora. Krajem godine u vrijeme božićnih blagdana veći broj radnika obično koristi jedan do dva tjedna godišnjeg odmora. Uz ove uobičajene uvjete i događaje karakteristične za kraj svake godine, kraj 2008. godine obilježile su sljedeće specifičnosti:

5 CONCLUSION

The negative price on the EEX spot market is a result of joint effect of several factors which occurred simultaneously at the end of 2008. The end of the year usually is not the period when economic activity increases, a new production cycle starts, etc. but it is a period when work is being brought to an end and when the holiday spirit starts to set in and people rest. At the end of the year, at the time of Christmas holidays, a large number of workers usually use one to two weeks of their annual vacations. Besides these usual conditions and events typical for the end of each year, the end of 2008 was also marked by the following specificities:

— nepovoljna opća gospodarska situacija i smanjivanje proizvodnje u velikom broju gospodarskih djelatnosti koje inače troše značajne količine električne energije za svoj rad, kao što su automobilska industrija ili proizvodnja aluminija,
— zaustavljanje proizvodnje u prosincu 2008. godine u automobilskoj industriji na mjesec dana i prinudan odmor za više od 250 000 radnika samo u Njemačkoj,
— umjereno i blago zimsko razdoblje s temperaturama zraka koje su neuobičajene za ovo doba godine,
— povoljni hidrološki uvjeti i povećani dotoci po iznosu i trajanju neuobičajeni u ovom godišnjem razdoblju,
— povoljno strujanje vjetra i povećana proizvodnja električne energije iz vjetroelektrana u noćnim satima.

Sve zajedno dovelo je do istodobnog smanjenja potrošnje i povećanja proizvodnje električne energije, što je pak uzrokovalo višestruko veću ponudu od potražnje i rezultiralo negativnom cijenom na spot tržištu EEX-a. Negativna cijena postignuta je noću kada je potrošnja električne energije uobičajeno najmanja. Međutim, temeljem pojave analizirane u ovom radu ne može se pojednostavljeno zaključiti hoće li se slične situacije ubuduće događati na spot tržištu električne energije. Vrlo vjerojatno neće svaki put uz povoljne hidrološke uvjete i pojačano povoljno strujanje vjetra tržišna cijena električne energije na burzi postizati dugotrajno negativne iznose. Također, preuranjeno je davati ocjene radi li se ovdje o rijetkoj pojavi na spot tržištu EEX-a budući da je uporaba negativne cijene na EEX-u uvedena relativno nedavno (od 19. prosinca 2007. godine na tržištu tijekom dana isporuke te od 1. rujna 2008. godine na spot tržištu). Čini se kako se odluka EEX-a o uvođenju negativne cijene brzo pokazala korisnom i opravdanom.

Zbog dobre povezanosti europskih EES-a stanje u zapadnoj i središnjoj Europi krajem 2008. godine odrazilo se na fizičke tokove snaga u hrvatskom EES-u i njegovom okruženju. Zabilježeno je povećanje razmjene električne energije noću preko hrvatskog EES-a, bez većih poremećaja i posljedica na njegov rad i sigurnost opskrbe krajnjih potrošača.

— unfavourable general economic situation and reduction of production in a large share of economic activities which normally use significant amounts of electricity for own operation, such as automobile industry and aluminium production,
— stopping the production in December 2008 in the automobile industry for a month and forced vacation for more than 250 000 workers in Germany only,
— moderate and mild winter period with air temperatures which are usually not realized in that time of year,
— favourable hydrological conditions and increased inflows, as regards their rate and duration, unusual for that time of the year,
— favourable wind circulation and increased electricity production from the wind power plants in the night hours,

All of this together caused a simultaneous reduction of consumption and increase of production of electricity, which in turn caused the offer to become several times higher than demand and resulted in a negative price on the EEX spot market. The negative price was achieved at night when electricity consumption is usually reduced. However, based on the occurrence analysed in this work, it cannot be simply concluded whether or not similar situations will happen in the future on the electricity spot market. It is quite probable that, with favourable hydrological conditions and increased favourable wind circulation, the electricity market price will not achieve lasting negative amounts each time. Moreover, it is too early to assess whether this occurrence is rare on the EEX spot market because the use of the negative price on the EEX was introduced relatively recently (on 19 December 2007 on the intraday market and as of 1 September 2008 on the spot market). It seems that the EEX decision on the introduction of the negative price turned out as useful and justified soon.

Due to good connection between the European electrical power systems, the situation in western and middle Europe at the end of 2008 impacted the power flows in the Croatian electrical power system and its surroundings. An increase of exchange of electricity at night through the Croatian electrical power system was recorded, without significant disruptions and consequences to its operation and security of supply of the end users.

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