Discussion of "Sustainable Electric Power System: Is It Possible? Case Study: Croatia" by Zvonimir Glasnovic and Jure Margeta

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Dear editor,

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Sincerely,

Dejan Brkić, Ph.D.

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The discusser would like to express his appreciation to the authors Glasnović and Margeta (2010) for presenting a possible way to establish sustainable electric energy system in Croatia. The discusser, however, would like to add few points and some literature references that might be of interest for readers.

Of the total energy consumed in Croatia, approximately 47% originates from petroleum and petroleum derivatives, 22% from gas, 13% from hydro-energy, 7.5% from coal, 5.5% from nuclear energy, while other sources account for 5% (Feretić et al., 1999). One third of the total energy consumed is transformed into electrical energy. Hydroelectric power plants cover approximately 28.3% of the electricity production (after Božičević Vrhovčak et al., (2006) between 40% and 60% which depending on the hydrological conditions), followed by thermal power plants with approximately 21.4% (from coal 7.7%, oil 5.5% and natural gas 8.2%) and nuclear power plants with approximately 10.4% (Saner et al., 2010). As seen in Božičević Vrhovčak et al. (2006), total installed capacity in Croatian electric power system is 4GW (52% in hydro, 29% oil, 8% in nuclear, 8% in coal and 3% in gas). Electricity consumption is about 15 TWh (Schneider et al., 2007). Croatia has a strong but not very efficient co-generation sector,

delivering 12% of the final energy (Lipošćak et al. 2006, Lončar et al. 2009, Uran and Krajčar 2009). As in all transition countries, electricity consumption in Croatia sharply declined after 1991. The reason for this in Croatia was not only the breakdown of the former communist regime but also civil war in former Yugoslavia that lasted from 1991 to 1995. For a decade now, Croatia has been experiencing increased electricity consumption, estimated to be growing by approximately 500GWh annually (Schneider et al., 2007). The net electricity import is 31%-40% of the total consumption (Schneider et al. 2007, Saner et al. 2010). About 0.421kg/kWh of CO_2 is released in atmosphere by electricity production in Croatia, where this value for continental Europe is estimated to 0.599kg/kWh of CO_2 (Saner et al., 2010). Compared to the energy consumption collapse in some transitional countries, Croatia has passed through a relatively short-term reduction of GHG emissions since 1990 because of higher energy efficiency of its pre-transition economy (Duić et al., 2005). The external costs caused by human health impacts of power plants in Croatia are comparable to those attached to the EU power plants (Božičević Vrhovčak et al., 2005).

All regions in Croatia are not equally suitable for certain renewable energy source. Significant differences exist between northern region (with part of Pannonian plain) and southern Adriatic region. Total coastal length of Croatia, including over 800 islands and islets, equals 5790 km. Balancing tool for islands that simulates the integration of renewable energy into energy-systems H_2RES was developed in 2000 by the Instituto Superior Técnico in Lisbon, Portugal and the Faculty of Mechanical Engineering and Naval Architecture in Zagreb, Croatia (Duić et al. 2008, Krajačić et al. 2009). H_2RES balances the hourly time series of water, electricity, heat, and hydrogen demand, as well as appropriate storages and supply over any user-defined period. The

tool has been specifically designed to increase the integration of renewable sources and hydrogen, into island energy-systems which operate as stand-alone systems. It can serve as a planning tool for single wind, hydro, or solar power systems, as well as for planning larger energy-systems.

The current share of renewable energy sources in electricity production in Croatia is high, around 50% (Božičević Vrhovčak et al., 2006). The potential of renewable energy sources for electricity generation still has to be carefully analyzed. The estimated potential varies between 3.5TWh in a moderate projection to 6TWh per year in the most optimistic perspective (Božičević Vrhovčak et al., 2006). In the year 2000, total primary energy consumed was about 360PJ (Karasalihović et al., 2003), out of which 75PJ was produced from renewable sources (Božičević Vrhovčak et al., 2006). In 1997, the Croatian government started five national energy programs dealing with renewable energy sources: BIOEN (biomass and waste), SUNEN (solar energy), ENWIND (wind energy), MAHE (small hydro) and GEOEN (geothermal energy). Within the national energy program BIOEN, it has been demonstrated that by 2030 at least 15% of the total energy consumed could be obtained from biomass (Schneider et al., 2007). More than 40% of Croatian territory is covered by forests, which means that the potential for biomass use is significant (Ćosić et al., 2011). Small hydro power plants (<10MW) can provide 2.37GWh annually of electrical energy in Croatia (Schneider et al., 2007). The use of wind energy in Croatia is currently very low, but future wind generators at the best sites in Croatia are close to becoming marginally competitive with fossil-fuel technologies (Feretić et al. 1999, Feretić and Tomšić 2005). On the Adriatic basin, in some area along the coast, a wind power of over 300W/m^2 and more than 2500kWh/m^2 per year may be gained with potential estimated at 200-400MW

installed capacity and about 800GWh yearly production (Poje and Cividini 1988, Urli and Kamenski 1998, Schneider et al. 2007). Solar potentials in Croatia with 2300-2800 sunshine hours per year in particular Adriatic islands can be estimated up to 5.5GJ/m^2 per annum with peak at Dubrovnik area (Desnica et al. 1988, Sinjeri and Kulišić 1994, Urli and Kamenski 1998, Franković et al. 1999, Hrastnik and Franković 2001). The potential of already discovered geothermal fields is 839MW of thermal energy and 30-47.9MW of electric energy (Schneider et al. 2007, Guzović et al. 2010). The results of the computational study by Davis et al. (2009) showed that abandoned oil wells (also exist in Croatia) have the potential to produce a significant amount of power when they are modified to become double-pipe heat exchangers. The calculations Davis et al. (2009) show that the net power produced from such a well may exceed 3MW for a bottom-hole temperature of 450K and an injection pressure of $30x10^5$Pa. This amount of power is not intermittent as with other renewable energy sources, and it may be available for peak demand as well as basic demand. The power produced varies and depends significantly on the down-hole temperature, the injection pressure, the injection velocity, and the geometric characteristics of the pipe (inner and outer radius and insulation thickness).

Electricity for hot water production with share of 43% represents significant share of the total consumption in Croatia (Atanasiu and Bertoldi, 2008). Electricity is used also for heating and this amount is significant in the residential consumption. Electricity for heating can be substitute with natural gas (Brkić and Tanasković, 2008). This can be done especially in northern part of Croatia, where natural gas supply system has been sufficiently developed. Natural gas can be significant if Croatia became transient country for natural gas from Russia to market of EU (Brkić, 2009). Natural gas can be also implemented at the Adriatic coast and islands (Vujčić et

al. 2000, Karasalihović et al. 2003, Dondi 2010). Energy efficiency is also very important for control of electric power consumption. Gas domestic boilers and electrical appliances with higher class of efficiency should be used (Brkić and Tanasković, 2008). Of course, district heating from remote plant in towns fired by gas can be also implemented. Share of sales of A class appliances, including domestic gas boilers in Croatia is 26.6% (Atanasiu and Bertoldi, 2008). The sales of the main domestic appliances in Croatia have a still higher share of lower energy classes. In Croatia was registered the lowest share of A class washing machines with 17.6% sold on the market (and only 0.8 of A+ class) comparing with the average share of 71.2% A and 8.4% A+ class from the EU markets (Atanasiu and Bertoldi, 2008). Building materials (e.g. windows) have become cheaper over the last decades in spite of significantly increasing energetic quality. Now, costs for building materials are 12% lower in Croatia compared with Germany.

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