COMBI THERMAL POWER PLANT OBROVAC 420 MW

Authors:

Mirko Grljušić
Branko Ora

SPLIT, May 2010.
A reliable and economical supply of electric power is a prerequisite for any competitive infrastructure and economy.

The key policies that regulate the production, transfer and distribution of energy in Croatia are:

- Energy Law (NN 68/01., 177/04.)
- Electrical energy market Law (NN 177/04., 76/07.)
- Gas market Law (NN 68/01.)
- Energetic activities regulations Law (NN 177/04.)
- Energy community contract confirmation Law (NN 6/06.)

Besides the set of laws, which are controlling the energy policies, the key acts that regulate and plan the energy development are The Strategy for Energetic Development and Program for Conduction of Strategy for Energetic Development.
The main regulatory institution for the energy market is Croatian Energy Regulation Agency (HERA). The agency services encompass the following activities:

- Issuing permits for conduction of energy activities
- Advising Croatian government in regards to payment amounts for connections to the power grid and for increase of power use.
- Advising Ministry on general conditions for energy supply.
- Advising Ministry on procedures and criteria for approval and development of production units.
- Issuing agreements for acquiring the status of favored producer.
There are thirteen (13) permitted producers in Croatia until now, and they are:

- HEP Proizvodnja d.o.o. Zagreb
- TE Plomin d.o.o. Plomin
- INA Industrija nafte d.d. Zagreb
- Adria Wind Power d.o.o. Sesvete
- Valalta d.o.o. Rovinj
- EKO d.o.o. Zagreb
- Hidro – Watt d.o.o. Zagreb
- Vjetroelektrana Trtar – Krtolin d.o.o. Šibenik
- Tudić elektro centar d.o.o. Šibenik
- Sladorana d.d. Županja
- Zagrebačke otpadne vode d.o.o. Zagreb
- Vjetroelektrana Orlice d.o.o. Šibenik
- Poljoprivredna zadruga Osatina Semeljci

The permit for transfer of electrical energy is given to:

- HEP Operator prijenosnog sustava d.o.o. Zagreb

www.hera.hr
The purpose of this study is to analyze the technical possibilities for developing thermal power plant fired by fossil fuels, therefore the main goal is to prepare the basic layouts and information for determining the thermal plant solutions.

Being that the natural gas is the cleanest fossil fuel as well as that the Bosiljevo - Split gas pipeline is planned to be built by October 2011., we have chosen it for this study as the main fuel source.
The production of all primary energy sources in the period from the year 2003. until 2008. grew at the annual average rate of 14%.

In the year 2008. electrical energy production in Croatia was 14.3 TWh.

In the year 2008. electrical energy consumption in Croatia was 18 TWh, +2.1% 2008/07.

Up to year 2020. will stop with production thermal and nuclear power plants of 1,100 MW.

Wind energy production has been increased as well, but it is still relatively small amount in total energy production.

*The rest include small thermal, hydro, wind and solar power plants.
• All types of energies have experienced increased import during the last six years.

• Therefore, the total energy import in Croatia grew at average annual rate of 2.6%.

• Furthermore, the import of electrical energy increased to 12.8% of average annual rate.

• High growth rate of 7.3% has been achieved in coal and coke import while only the growth of natural gas was moderate 1.5%.

• The crude oil import decreased at average annual rate of - 4.2%.
During the period from 2003. until 2008, Croatia has experienced an increase of 0.9% average annual growth of the total energy consumption.

In the natural gas consumption a certain stagnation has been registered where the annual average rate during the viewed period of time was only 1.9%.

The fastest increase trend has been accomplished in electrical energy consumption with 11.1% average annual growth.

Forecast of electrical energy consumption and prime energy consumption in Croatia (1.6% annual rate) [dr.Feretic]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption TWh</td>
<td>12.68</td>
<td>16.5</td>
<td>21 - 25</td>
<td>25 - 30</td>
<td>40 - 49</td>
</tr>
<tr>
<td>New Power required MW</td>
<td>-</td>
<td>-</td>
<td>1470 - 2236</td>
<td>3863 - 4798 +</td>
<td>6436 - 8236</td>
</tr>
<tr>
<td>Consumption kWh/capita</td>
<td>2800</td>
<td>3454</td>
<td>4133 - 5166</td>
<td>5146 - 6175</td>
<td>7400 - 9057</td>
</tr>
<tr>
<td>Prime energy consumption PJ</td>
<td>348</td>
<td>392</td>
<td>402 - 489</td>
<td>418 - 502</td>
<td>544 - 669</td>
</tr>
<tr>
<td>Consumption GJ/capita</td>
<td>77</td>
<td>82</td>
<td>83 - 101</td>
<td>86 - 103</td>
<td>100 - 124</td>
</tr>
</tbody>
</table>

* Power of new installed plants include replacement old existing Thermal Power plants and NE Krško
### MIT Forecast of Electrical Energy Consumption in 2050. [10]

<table>
<thead>
<tr>
<th></th>
<th>Population millions</th>
<th>Total consumption of el. energy in TWh</th>
<th>Consumption of el. energy in kWh per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croatia</td>
<td>5</td>
<td>4</td>
<td>12.6</td>
</tr>
<tr>
<td>B&amp;H</td>
<td>4</td>
<td>3</td>
<td>2.6</td>
</tr>
<tr>
<td>Hungary</td>
<td>10</td>
<td>7</td>
<td>35.1</td>
</tr>
<tr>
<td>Austria</td>
<td>8</td>
<td>6</td>
<td>54.8</td>
</tr>
<tr>
<td>Finland</td>
<td>5</td>
<td>5</td>
<td>82.0</td>
</tr>
<tr>
<td>Norway</td>
<td>4</td>
<td>5</td>
<td>112.5</td>
</tr>
<tr>
<td>USA</td>
<td>283</td>
<td>397</td>
<td>3 621.0</td>
</tr>
<tr>
<td>Russia</td>
<td>145</td>
<td>104</td>
<td>767.1</td>
</tr>
<tr>
<td>Ukraine</td>
<td>50</td>
<td>30</td>
<td>151.7</td>
</tr>
<tr>
<td>China</td>
<td>1 275</td>
<td>1 462</td>
<td>1 206.3</td>
</tr>
</tbody>
</table>
• The total energy consumption per capita in Croatia in the year 2006 was 2,209 kg of oil equivalent, therefore 41.6% less than in the European Union (EU15) countries.

• According to the figures in Croatian Strategy for energetic development, its own energy supply will decrease during the next 20 years. In the year 2008, it was 47.7% which represents the decrease in relation to the year before and fits in the current trend of reduction in the previous period. This trend will continue in the future, therefore in the year 2030, it will be cca 28% and the remaining needed energy for Croatia will be imported.

• The shown figures imply that there is an urgent need for development of new electro-energetic plants in order to decrease dependence on import of energy in Croatia.
SIEMENS: Renewables are gaining in importance, but fossil fuels will continue to be mainstay [7]
LOCATIONS OF HYDRO AND THERMAL POWER PLANTS IN CROATIA
The referenced location is placed at town Jasenice just near local road, and 10 km from the highway Zagreb - Split.

The location is places 3.5 km from the town Obrovac and 35 km from the city of Zadar.

The location is 7.5 km from the sea shore as well as 1.5 km from the River Zrmanja.

Max. 7 km of network connection is needed in order to connect to the 400 kV transfer network at RHE Velebit.

The area is topographically suitable with almost no obstacles for development of any kind of fossil fuelled thermal power plant.
In the surrounding area of 50 km from location there are 80,000 permanent habitants in 15 settlements and 3 cities. The tourism aspect of the location is not significant.

As far as the climate is concerned there are winds in the area mostly blowing from the north and north-east (bara) and rarely from the south-east direction (jugo).

The sea area near the location is the closed Novigrad sea and Velebit channel.

Combi PP Jasenice requires 260m x 115m = 29,900 m². LUX ENERGIJA has the lot of nearly 500,000 m².
- Efficiency of classical Steam turbine plants are cca 40%. New supercritical steam turbines (pressure up to 285 bar, temperature up to 620 °C) plant efficiency 43 to 46%. Under construction are new supercritical steam turbines with efficiency over 50%, 700 °C and 350 bar.

- The highest efficiency up to 60% are of Combi Power Plant but they can use natural gas and/or extra light fuel oil only.
- The unit ratings for centralized plants are in range from 100 to 1000 MW.
- Decentralised plants are sited and built locally to meet the needs of specific customers, often in cogeneration mode up to 100 MW.

Last years has been contracted over 100 GW/year of new Power Plants.
- 80% Gas & Steam turbines + Diesel engines (Turbine share: 60% combi, 40% Steam)
- 14% Hydro Power (big and small)
- 4% Nuclear Power
- Less than 2% Renewable energy
Relative power generation costs for coal and natural gas in % [11]
The producers of the largest gas turbines have oriented themselves into achieving the most possible single power, and being that within the combi process in steam turbine additional 50% of power is created, nowadays the large combi power plants produce the power of approximately 250 MWe, 420 MWe and latest 530 MWe per unit.

For that reason, the recommendation of optimal solution is combi power plant operating on natural gas with the approximate power 420 MWe.

Indicative Plant Size 420 MW [1]
TECHNICAL SOLUTION CHOICE

Layout of Combi Power Plant Jasenice 420 MW [1]
With respect to the impact on environment combined plant using natural gas as fuel is definitely the most attractive option. Compared to other variants with fossil fuels, the aforementioned combined plant ensures that crude and liquid waste production is almost non-existent, and there are no emissions of SO$_2$, because natural gas does not contain sulphur. The biggest issues are linked to NOx emissions and noise.

Special devices for combustion that are reducing NOx compounds generation, have to be installed so as to abate NOx at the regulated value.

The noise issue can be resolved through adequate planning on locations which represent the key noise sources, and with supporting buildings.
• For the suggested plant, natural gas is predicted as a fuel. PLINACRO d.o.o. anticipates the possibility of gas consumption on the subject Thermal Power plant by the October 2011.

• Fuel will be obtained from the gas pipeline at distance of 750m from Jasenice Power Plant at 50 barg pressure. This enables gas delivery to combustion chamber at nominal pressure of 30 barg. Gas turbine and other systems are developed to operate at gas pressure of 27 barg, without load decrease.

• Equipment for the gas supply shut-out, has to be implemented within combi power plant, furthermore, equipment for liquid and gas particles segregation, as well as pressure regulator prior to entering the combustion chamber at all operating modes, have to be installed.

• Device for gas consumption measurement is installed by the gas supplier, and the turbine producer installs his flow meter just before combustion chamber due to the fuel consumption verification.

• Combustion system has to be predicted with exclusively natural gas combustion, in accordance with Croatian standards regarding allowed emissions.
Consumption of natural gas as a fuel during plant’s operations depends on more factors.

For new plant, assuming that the plant’s efficiency is 58.2% while ignoring variations in pressure and temperature of surrounding air, with lower heating value of natural gas amounting 34,127 kJ/nm³ (referring to pressure 101,325 Pa and temperature 288.15 K or 15°C) the fuel consumption is, based on the table from the above, for Siemens plant operations SCCS-4000F Single Shaft of 416.0 MW around 20.94461 nm³/s, or 527,804,100 nm³/year with the operation of 7000 h/year.

This plant’s efficiency is 58.2% which does not fall among the highest values.
Water, essential for plant’s cooling can be used from two sources:

- Water from river Zrmanja, or seawater
- The amount of water needed for the aforementioned purpose is approximately $5.1 \, \text{m}^3/\text{s}$, what can not be obtained from river Zrmanja.

- By installing cooling tower, the required amount of water for cooling is greatly decreasing, but the initial investments are augmenting.

- General recommendation: implementation of combi power plant as close as possible to the river or sea front so as to decrease the cost of the pumping installation and electricity consumption for plant’s operations. Environmental Study should give information about possibility of using river water for additional cooling of steam turbine plant.
• Price for combi power plant is currently around 750 €/kWe key in hand, if the fuel is natural gas, and cooling is from river or sea. Two fuels, liquid as a reserve and cooling towers increase the plant’s price. For the plant of 420 MWe the overall price amounts to 310 millions €.

• Individual equipment price, documentation, construction works and installation is difficult to establish without concrete offers. The following is a general rule: equipment 70% (gas turbine 25%, boiler 20%, steam turbine 20%, switchyard 5%, auxiliary facilities 3%, installation 7%, construction works 10%, engineering (documentation, conduction) 5%, miscellaneous 5%.
According to the latest available information, the price for large users increased for transport expenses should be significantly lower than 1.70 kn/nm³. Basically, the price of gas for large users such as TE Obrovac is subject to negotiation which includes discounts and bonuses.

For the purpose of our calculation the price of gas is 1.25 kn/nm³, increased for transport expenses of 0.133 kn/nm³, which constitutes the gas price of:

1.383 kn/nm³ or 0.189 € cent/nm³.
In the process of determining the sales price of electricity we used the method of eligible expenses plus profit, which includes return of capital rate, and prices based in European energy exchange.

For the purpose of our calculation the price of electricity is:

0.547 kn/kWh or 7.5 € cents/kWh.

*www.eex.de*
• Thermal power plant Obrovac 420 MW will operate as an independent limited liability company LUX ENERGIJA d.o.o., Zagreb, Ilica no. 93.

• The company will employ 34 top quality electrical/mechanical engineering professionals mainly

• Next to general manager and assisting staff on administrative positions another 10 people will work on setting, while personnel working on production will count 24 employees

• Plant cleaning and security will be outsourced, and handled by specialized local companies
"R" indicates activity description throughout implementation period, and "M" indicates months.
## PREFEASIBILITY INVESTMENT VALUE

<table>
<thead>
<tr>
<th>R.b.</th>
<th>INVESTMENT SPECIFICATION</th>
<th>AMOUNT €</th>
<th>IN %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Basic (permanent) funds</td>
<td>346,300,000.00</td>
<td>96.2</td>
</tr>
<tr>
<td>1.1.</td>
<td>Constructible land and communal charges</td>
<td>12,500,000.00</td>
<td>3.5</td>
</tr>
<tr>
<td>1.2.</td>
<td>400 kV TE Obrovac – RHE Velebit</td>
<td>11,000,000.00</td>
<td>3.0</td>
</tr>
<tr>
<td>1.3.</td>
<td>Gas turbine</td>
<td>77,500,000.00</td>
<td>21.5</td>
</tr>
<tr>
<td>1.4.</td>
<td>HR Boiler</td>
<td>62,000,000.00</td>
<td>17.2</td>
</tr>
<tr>
<td>1.5.</td>
<td>Steam turbine</td>
<td>62,000,000.00</td>
<td>17.2</td>
</tr>
<tr>
<td>1.6.</td>
<td>Distribution center</td>
<td>15,500,000.00</td>
<td>4.3</td>
</tr>
<tr>
<td>1.7.</td>
<td>Supporting plants</td>
<td>9,300,000.00</td>
<td>2.6</td>
</tr>
<tr>
<td>1.8.</td>
<td>Installation</td>
<td>21,700,000.00</td>
<td>6.0</td>
</tr>
<tr>
<td>1.9.</td>
<td>Construction works</td>
<td>31,000,000.00</td>
<td>8.6</td>
</tr>
<tr>
<td>1.10.</td>
<td>Non-material funds</td>
<td>43,800,000.00</td>
<td>12.6</td>
</tr>
<tr>
<td>2.</td>
<td>Operational expenditure</td>
<td>13,835,568.00</td>
<td>3.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>360,135,568.00</td>
<td>100.0</td>
</tr>
</tbody>
</table>
PROFIT AND LOSS STATEMENT

TOTAL REVENUE
TOTAL EXPENDITURE
GROSS PROFIT
TAX
NET PROFIT

(in 000 €)
EFFICIENCY ESTIMATES

- Pay-off Period: by the fifth year
- Current Net Value: 271,014,000 €
- Relative Current Net Value: 0.7525
- Internal Rate Profitability: 19.939277652%
- Debt Service Capacity Ratio: positive (n>1)
- Break-even Point: positive
- Cash flow: positive in all years (n>0)
SENSIBILITY ANALYSES

Sensibility Analyses – B. option

B. option is based on the assumption that the price of electricity is decreased by -10%, as well as increased price of natural gas by +10%.

- **Net Profit**: positive for all years
- **Pay-off Period**: by the eighth year
- **Current Net Value**: 60,504,000 €
- **Relative Current Net Value**: 0.1680
- **Internal Rate Profitability**: 9.7431579%
THANK YOU FOR YOUR ATTENTION!