NORBERT ROSA*

Energy and emission efficiency of Cogen power

About the presented cogeneration technology we could state that it has a higher (2.5-fold) emission efficiency in relation to CO_2, beside its energy efficiency (1.5-fold) therefore its environmental load decreasing effect is unquestionable. It is expected that it will be a significant factor of the future energy mix. We tried to emphasize the emission efficiency of the cogeneration technology by its introduction, since its interpretation is much harder because of its complexity.

Besides its emission efficiency, other loads can also be considered as goals in other studies for the classification of power plants (soil load, water load, noise, hazardous and communal wastes, packaging materials, applied chemicals, etc.). For this the detailed knowledge of production technologies are needed, detailed inventory has to be prepared by the evaluation of material- and energy flows and in this way the total environmental impacts can be estimated e.g. by the referenced life cycle assessment methods (page 156 of [8]).

THE EU CLIMATE AND ENERGY PACKAGE

Climate change has become a business reality to which companies must react. As a consequence business executives are asking themselves questions such as: How should my company prepare for a carbon-constrained world? Do we know how much greenhouse gases my company emits to make products (or make the energy I consume or produce)? What does a carbon footprint look like?

Without action global emissions are forecast to double by 2030. The Intergovernmental Panel on Climate Change, advisory body to world leaders concluded in 2007 that global carbon dioxide emissions would need to fall by 50-85% by 2050 to prevent average global temperatures from rising more than 2 °C [1].

In March 2007 the EU's leaders endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness. They committed Europe to transforming itself into a highly energy-efficient, low carbon economy.

To start this process, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020. These are:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

Collectively they are known as the 20-20-20 targets.

The EU leaders also offered to increase the EU's emissions reduction to 30%, on condition that other major emitting countries in the developed and developing worlds commit to do their fair share under a global climate agreement.

In January 2008 the European Commission proposed binding legislation to implement the 20-20-20 targets. This 'climate and energy package' was agreed by the European Parliament and Council in December 2008 and became law in June 2009 [2].

---

* Synergy Kft., műszaki vezető.

What exactly will change? The package of EU climate and energy measures approved in December 2008 implements these targets.

- For power plants and energy-intensive industries - emissions to be cut to 21% below 2005 levels by 2020. How? By granting fewer emission allowances under the EU Emissions Trading System (ETS) (covering some 40% of total EU emissions).
- For sectors not covered by the ETS (e.g. transport (except aviation, which will join ETS in 2012), farming, waste and households) - emissions to be cut to 10% below 2005 levels by 2020.
- How? Through binding national targets (with higher reductions for richer countries and limited *increases* for the poorest ones).
- Renewables will produce 20% of all the EU's energy by 2020.
- How? Through binding national targets (from 10% for Malta to 49% for Sweden). At least 10% of transport fuel in each country must be renewable (biofuels, hydrogen, 'green' electricity, etc.). Biofuels must meet agreed sustainability criteria.
- Promotion of safe use of carbon capture and geological storage (CCS) technologies which could eventually remove most carbon emissions from fossil fuels used in power generation and industry [3].

The Copenhagen climate summit ended on the 19th of December 2009 with its climate agreement (Copenhagen Accord) is between the pessimistic (Nopenhagen) and the optimistic (Hopenhagen) expectations.

According to the evaluation of the UN chief secretary, the document could not contain all the wishes of everyone but an important starting point, or a good frame so that to make a legally binding agreement in the future. By all means, the document is executable immediately and there are sources and assets behind, the chief secretary said.

The compromise might be evaluated poor or good still we have to notice something. It seems, that with this action the starting point of a new political global system is observed in some extent within the frame of the UN. And it is promising. Sanguineous environmentalist might criticize the agreement but not much more could be expected after the warning of the participants involved in the main conflict. Even the president of the EU Committee advised not to be overoptimistic before the summit. In contrary EU industry warn him not to increase the CO_2 reduction target from 20% to 30% [4].

ROLE OF THE ENERGY SECTOR

The energy sector is connected with the problem in several ways. Firstly as a denominated sector, secondly as one of the significant emission factor of CO_2, NO_x, SO_2 and fine particles. And what will be the new (if any) CO2 reduction target in the EU? We will see, but let's examine the Hungarian energy situation in the following.

The electric energy consumption in Hungary was 42.75 TWh in year 2006, the production of domestic power plants was 35.5 TWh thereof, the excess demand was covered by import of electric energy. If we examine the breakdown of production according to fuel types, we can establish that the majority of energy generation was produced on the basis of natural gas/oil (38%), with negligible ratio of oil thereof, the next category is electric energy generated by using nuclear fuel, ratio which is the same magnitude 37%. The coal based electric power generation is 20% (lignite based 77% thereof). The ratio of electric power production based on renewable energy sources is 5% of domestic production (the largest ratio is biomass, 65%, the ratio of other renewable energy sources are 22%, water 10%, wind 3%) [5].

Taking into consideration the formerly prognosed demand, it is necessary to increase both the capacity of small power plants, below 50MW, and the capacity of classic, traditional large power plants. We have to take into consideration the specific conditions of the country.

From the existing 9,000 MW total installed electric power generation capacity 4,000 MW will shut down until 2025, 0.5 thousand MW import will cease, while the demand will increase by 0.5-1.5 thousand MW. It means that in the next 1.5 decade 5-6,000 MW capacity should be installed ([6] page 45). Regarding development of large power plants there was announced several investment idea in the last one-1.5 year, most of them were installation plan of gas fired power plants (See *Table* on [6] page 44). The development ideas of traditional coal based (domestic lignite, import coal) and nuclear power plant development will be subject of future decisions. On the basis of „pillars" of „safety of supply" and „sustainability" following statements can be made, which partly are necessarily contradicting each other.

- for ensuring the safety of supply, i.e. for decreasing the dependence on import and dependence on import of natural gas, the solution would be the use of domestic lignite or development of nuclear power plant,
- from the sustainability point of view, taking into consideration the quantity of emission of green-house gases, besides the use of renewable energy sources, use of cogeneration power plant and/or combined cycle technology could be the solution against coal fired alternatives, but in longer term the nuclear power plant development can be mentioned here too as a potential real solution [5].

Taking into consideration the ratio of natural gas consumption and the above mentioned future ideas, it is reasonable to examine the efficiency and emission issues of natural gas fired power generation plants and especially the modern version of it, the cogeneration power generation technology, and illustrate it with an example. The most important question which must be answered is how these technologies, and the technical – technological efficiency associated with them can assist in decreasing the load on environment.

It is known as paradox of JEVONS, that energy efficiency developments are oriented more in direction of increase rather than of decrease of energy consumption. (Or we can mention the statement that the energy is the propellant of modern economic systems, rather than these systems are creating the energy demand ([7] page 1464). Independently from pro and contra arguments it is rather unlikely that every improvement in energy efficiency finally will be reversed ([7] page 1468), therefore it is reasonable to present the favourable effect of these technologies on environmental load.

There was a former study performed on Hungarian energy mix, and assessment of life cycle thereof, which examined what amount of environmental load is associated with production of 1 MJ product in the Hungarian electric energy system, in cases of use of different primary energy sources, from exploration until emission and disposal of wastes thereof ([8] from page 153). The study established in detail examination that it is influenced by many factors, and especially it is difficult to measure the effect of primary sources if cogeneration of heat and electric energy is performed ([8] page 174).

ENERGETIC BENEFIT OF COGENERATED ENERGY

The "benefit" of cogeneration can be presented at the input side as follows:

Primary energy is used in a common technological process, in which heat and electric energy is simultaneously generated.

Let suppose, that 1 GJ natural gas is feeded into a gas motor, wherefrom in a technological process 0.4 GJ electric energy (40%) and 0.42 GJ heat energy (42%) can be produced (total efficiency is 82%) taking into consideration the efficiency parameters of the process.

The same quantity of electric energy in a condensation power plant of 35% efficiency would be produced from 1.142 GJ natural gas, and 0.42 GJ heat energy could be produced from 0.456 GJ natural gas, if we produced it in a boiler with the efficiency of 92%. The conclusion is that 1.598 GJ natural gas would be used instead of 1 GJ if we would not use cogeneration (1.5-times higher efficiency) [9].

(If we could increase the efficiency of traditional condensation power plant to the efficiency of gas motor, then the necessary excess energy input would not be much less.)

Cogeneration establishments generating electric energy and heat are modern, they are easy to control, they are designed taking into consideration the decrease of environmental load especially, and, their contribution can be quantified and are significantly beneficial as it will be shown below.

(The cogeneration also has some disadvantages originated from the applied technology, namely the demand for electric energy and heat energy must exist simultaneously in order to utilize the beneficial specific characteristics of the technology.)

The support of useful heat demand based cogeneration production is also preferred by the EU (2004/8/EC Directive), taking into consideration that even a small power plant (less than 50 MW) with larger capacity can economize many hundred thousands GJ heat energy as primary energy using the cogeneration technology.

In addition to cogeneration technology we have to mention the trigeneration, where in addition to production of heat and electric energy the so called cold energy is also produced, i.e. the heat or part of it is used in absorption type refrigerators, and is supplied in this form to the customers [9].

The standpoints are quite uniform regarding the energy efficiency issue above, but evaluation of certain situations is not always unambiguous even there, e.g. what is the real operation mode within one technological solution, what is the ratio of different energy types, etc.

Already one day or one week average value can mask out the difference between operation conditions, and it is more important in case of average values of longer periods. As an example we present a case with two different operating conditions of a given heat supply where auxiliary equipments also exist. In addition to the cogeneration equipment such type of equipments are also necessary for the safety of supply in a given heat supply system, and, the heat generation has usually higher priority than the electric energy generation in such systems.

The following can be observed in case of a power plant which has two cogeneration blocks.

In case of same heat generation (let assume now 100 t/h) if only one block is operating, then it shall produce 16 MW electric energy and 30 t/h heat energy, and considerable part of heat energy will be produced in the auxiliary units (70 t/h) using 13,000 m^3/h natural gas as total for the production. If the same 100 t/h heat energy will be produced in two blocks, it means that it is operated at e.g. 48 MW (2×24 MW) electric power level, we will cogenerate 80 t/h heat, therefore only 20 t/h heat capacity is necessary from auxiliary boiler unit. In this case the natural gas demand will be 18,000 m^3/h.

Because the same heat quantity is produced, the production target value is the same, but the implementation is very different, what can be a result of several technical and economical reasons temporarily, but it can be seen, that in this case practically using *"plus 5,000 m^3/h natural gas 32 MW electric energy was produced"*, which is a very good result, taking into consideration that one block in the examined case in reality uses approx. 7,000 m^3/h natural gas for only 25 MW! [10]

In addition to the above the judgement of cogeneration power plants is not simple in that respect how the outputs, the emissions are evaluated and what kind of data are compared.

EMISSION EFFICIENCY

Let's examine the output side as a case study and as a typical example in the following. BC-Erőmű Kft. (as a cogeneration producer) has been operated with the following operating data in 2007 [10].

Table 1
Monthly production of BC-Erőmű in the year 2007 ([10])

Month	Steam (tons)	Electricity [MWh]
January	64,561	32,602
February	54,856	27,241
March	55,514	28,239
April	58,237	31,245
May	56,140	30,396
June	52,759	28,124
July	50,423	25,669

Month	Steam (tons)	Electricity [MWh]
August	43,117	12,157
September	56,582	28,631
October	57,467	31,722
November	58,631	32,752
December	60,841	33,465
Sum	669,128	342,243

We have collected the emission and operating hours data of the main components in the *Table 2* (see the next page).

The annual NO_x emission was 112 tons, while CO was 70 tons and CO_2 was 210,000 tons. On the basis of the operation hours of the non-cogeneration (AB1 and 2) equipment we could state, that they represent only 12%, with regard their production – as a result of their average load comparison to other equipment (HRSG1 and 2), – they represent even less, only approximately 5%, while their emission is only 3% of the total annual value in respect of CO_2, 2% of NO_x and minimal amount of CO.

It can be seen on the level of emission quantity that the emission of CO_2 is higher by 3 orders of magnitude than the NO_x and CO emissions (~200,000 tons of CO_2 against approximately 100 tons of NO_x and CO). Therefore cogeneration power plants are treated as more beneficial primarily because of their CO_2 emission.

Table 2
Monthly emission data of BC-Erőmű in the year 2007 ([10])

		January	February	March	April	May	June	July	August	Septem-ber	October	Novem-ber	Decem-ber	Year total kg	Year total tons
HRSG1	Op. hours	736	504	723	707	744	681	722	354	680	744	705	736		
	NO_x [kg/h]	6	7	6	7	5	6	6	6	7	7	7	7		
	CO [kg/h]	5	4	8	5	6	8	9	10	4	3	3	2		
	CO_2 [kg/h]	13241	13010	11829	12902	11953	11875	11300	11298	12295	12366	13329	13229		
	Dust [kg/h]	0	0	0	0	0	0	0							
	NO_x [kg]	4593	3276	4389	4617	3698	3923	4541	1982	4998	5334	4759	4806	50915	51
	CO [kg]	3871	2162	5755	3577	4650	5625	6195	3487	2618	2061	1805	1582	43389	43
	CO_2 [kg]	9745501	6557060	8552454	9121778	8892720	8086984	8158918	3999418	8360539	9200542	9397135	9736323	99809371	99809
	Dust [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HRSG2	Op. hours	737	669	684	711	744	701	634	488	681	745	713	729		
	NO_x [kg/h]	7	8	7	7	6	6	7	6	8	8	8	7		
	CO [kg/h]	3	3	3	2	3	4	4	7	2	3	2	2		
	CO_2 [kg/h]	13212	13740	12011	12825	11957	11570	11308	11256	12373	12616	13349	13171		
	Dust [kg/h]	0	0	0	0	0	0	0							
	NO_x [kg]	5203	5272	4754	5247	4241	4297	4286	2786	5516	5863	5390	5293	58148	58
	CO [kg]	2506	2288	2148	1678	2113	2874	2720	3333	1600	1900	1141	1604	25904	26
	CO_2 [kg]	9736964	9191980	8215531	9118404	8896112	8110696	7169082	5493094	8426333	9398562	9517787	9601674	102876219	102876
	Dust [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AB1	Op. hours	90	187	100	25	0	43	51	266	82	0	26	37		
	NO_x [kg/h]	1	1	1	1	0	0	1	1	1	0	1	1		
	CO [kg/h]	0	0	0	0	0	0	0	0	0	0	0	0		
	CO_2 [kg/h]	3226	3069	3248	3759	0	3083	3093	3918	3941	0	3218	3853		
	Dust [kg/h]	1	1	2	4	0	5	4	4	4	0	3	3		
	NO_x [kg]	103	215	122	25	0	8	46	271	119	0	19	37	965	1
	CO [kg]	13	21	20	4	0	9	16	40	23	0	11	6	162	0
	CO_2 [kg]	290322	573970	324812	93987	0	132582	157754	1042223	323139	0	83664	142551	3165004	3165
	Dust [kg]	116	262	158	99	0	228	179	971	348	0	76	117	2554	3

Table 2 (continued)
Monthly emission data of BC-Erőmű in the year 2007 ([10])

		January	February	March	April	May	June	July	August	September	October	November	December	Year total kg	Year total tons
AB2	Op. hours	114	174	100	26	0	60	49	342	97	030	43	224		
	NO_x [kg/h]	1	1	1	2	0	1	1	2	2	1	1	1		
	CO [kg/h]	0	0	0	0	0	0	0	0	0	0	0	0		
	CO_2 [kg/h]	3843	2952	3331	4008	0	3167	3005	3954	3959	2564	3149	3008		
	Dust [kg/h]	1	1	2	2	0	2	1	2	2	1	1	5		
	NO_x [kg]	136	195	134	46	0	79	68	568	183	33	51	284	1777	2
	CO [kg]	15	14	12	6	0	10	8	41	7	3	6	47	169	0
	CO_2 [kg]	397114	513615	333076	104221	0	190045	147221	1352371	384011	76923	135422	673763	4307782	4308
	Dust [kg]	162	237	162	46	0	114	73	670	193	36	55	1062	2810	3
HRSG1,2	NO_x [kg]	9796	8548	9142	9864	7938	8220	8827	4769	10514	11198	10149	10099	109064	109
	CO [kg]	6377	4450	7903	5255	6753	8499	8915	6820	4218	3961	2946	3186	69293	69
	CO_2 [kg]	19482465	15749040	16767985	18240182	17788832	16197680	15327999	9492512	16786872	18599104	18914922	19337997	202685590	202686
	Dust [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AB1,2	NO_x [kg]	238	410	256	70	0	87	115	839	302	33	70	322	2742	3
	CO [kg]	27	34	32	10	0	20	24	81	30	3	17	53	332	0
	CO_2 [kg]	687436	1087585	657888	198208	0	322627	304975	2394593	707150	76923	219087	816314	7472786	7473
	Dust [kg]	278	498	320	145	0	342	252	1641	541	36	131	1179	5364	5
Sum	NO_x [kg]	10034	8958	9398	9934	7938	8307	8942	5608	10816	11231	10219	10420	111806	112
	CO [kg]	6405	4485	7935	5265	6763	8519	8939	6901	4248	3964	2963	3240	69625	70
	CO_2 [kg]	20169902	16836625	17425873	18438390	17788832	16520307	15632974	11887105	17494022	18676027	19134009	20154311	210158376	210158
	Dust [kg]	278	498	320	145	0	342	252	1641	541	36	131	1179	5364	5

It does not mean that the NO_x, and CO emissions would not be important, but these values are influenced by several other factors (primarily the type of firing, the technical parameters of combustion, etc.). Very strict NO_x and CO limit values have been defined for the individual equipments which have to be met. For example, at the inspected power plant, the NO_x emission of the gas turbine is fitted with a so-called DLE system - dry low emission natural gas burner system, which is intervening at the actual load and feeds dilution air in order to decrease NO_x formation at high temperature.

If we are examining the national emission rate of NO_x, we could see that its annual value is approximately 280,000 tons which main contributor is traffic. According to estimates (made on the basis of previous years' data) the emission of power plants are below 50,000 tons [11]. The annual value remains the same, which is caused by the increasing emission rate of traffic and the decrease of the emission rate by power plants. The comparison of the NO_x emission between the traditional coal based power plants and the gas based cogeneration power plants has been carried out in the following way:

We have compared one of the main Hungarian coal based power plant to the natural gas based one described in this study. The electric energy capacity of the coal fired power plant is five times of the natural gas one (page 32 of [12]) and its annual production is approx. four-fold. In addition to this fact, the heat production is six times higher for the latter one, i.e. the heat output of the cogeneration technology - specifically - very significant. Examining the NO_x emission on the basis of the available data (page 34 of [12]) we can state that, the emission of coal based technology is 15 times more than natural gas one. So if we examine only the electric energy production without the heat generation, then we can declare that the 4-fold production combines with 15-times more NO_x emission rate.

As compared to NO_x emission data, there is fewer summarized data available about CO emission. CO emission data are not published by e.g. energetic-statistical publications [12]. There is only NO_x emission data in the study prepared in 2006 on the environmental economy benefits of district heating [13] and the energetics books published in the field of cogeneration [14] also only emphasize the CO_2 emission reduction as the environmental protection benefit of this kind of technology. In respect of CO emission we could state that on the level of equipment (e.g. traditional boilers fired by natural gas) the CO emission is very favourable, well controlled, while cogeneration gas turbines operated on part load might have very infavourable CO emission.

We could examine not only annual summarized data, but snapshot values too. According to these values and illustrating with an example we could state the followings [10]:

At 40 t/h steam production (performance level): There was 0.38 kg CO, 1.74 kg NOx and 5,570 kg CO_2 emission, when the natural gas fired boiler had produced 40 tons of steam during 1 hour (on the basis of data obtained on 8th April 2009). In comparison to this, the gas turbine at the same performance level (i.e. 40 t/h steam production) as well as with the cogeneration of 19 MWh electricity (at 19 MW per one hour) had an 2.7 kg CO, 6.36 kg NO_x and 11,200 kg CO2 emission (on the basis of data obtained on 9th July 2007). In other words, the generation of 19 MWh electric energy costed 2.3 kg CO, 4.6 kg NO_x and 5,600 kg (surplus) CO_2. Expressed in energy equivalent, the 40 t/h steam production with the specified pressure and temperature (30 bar (g), 370 °C; the energy content of the steam is approximately 3.1 GJ/t) results 124 GJ/h, which means 34.44 MW energy production.

(As it is well known, 1 W= 1 J/s from which 1 GW=1 GJ/s; 1 GJ/h=1/3600 GW=1/3.6 MW=0.2778 MW.) As it follows from the above mentioned, the 19 MWh electric energy generation beside the 34.44 MWh steam production accompanied by a relatively significant, 2.3 kg CO, 4.6 kg NO_x and 5,600 kg CO_2 emission. Of course, this „surplus" related to the electric energy was well seen at the energetic comparison, it means, that we could produce steam in a boiler with a high (92-93 %) efficiency, but in this case we got only one product – steam – and the efficiency of electric energy generation is only around 40%. It is much worse in a traditional coal based power plant. (But, as we have seen, in case of cogeneration the total efficiency could reach 80-85%.)

The comparison of CO and NO_x emissions is more difficult if we would like to compare cogeneration technology with the non-cogeneration type. So it is not similar to the one we have made with primary energy sources and stated their savings; although CO_2 is comparable and measurable. According to the data shown in Table 3 we could calculate the CO_2 emission resulted by the generation of 19 MWh on natural gas base (19 × 0.502 tons = 9.538 tons = 9,538 kg, and just compare it to the above measured 5,600 kg value):

Table 3
Specific CO_2 emission rate of electric energy generation in case of natural gas and coal based production ([10])

Electricity - 1 MWh production	Natural gas	Coal
Required quantity (m^3, kg)	265	762
Efficiency (%)	40	35
Calorific value (MJ/ m^3, kg)	34	13.50
Emission factor (g/MJ)	56.1	95.1
Oxidation factor	0.995	0.99
Released CO_2 (t)	0.502	0.97

As it can be seen and represented by the specific values, the emission rate is almost double in case of the coal based production. On the page 366 of [14], we find relatively similar values for the specific CO_2 emissions.

The CO_2 emission benefit of cogeneration can be quantified by the comparison of these two data, as the energy input (comparison of traditional power plant and cogeneration power plant). We obtained the same rates by the comparison of our natural gas based power plant and the previously mentioned coal based power plant. After all, the 4-fold difference in production accompanied by almost 8-fold CO_2 emission (As you can see on page 34 of [12] it means 210,000 tons for the natural gas power plant and 1,630,500 tons for the coal based one, which values does not include the extra heat output). Following the scheme of *Table 3*, we could calculate the CO_2 emission rate related to one unit of heat energy for the different energy sources (see *Table 4*), as well as the CO_2 emission rate related to a given unit of heat - that is cogenerated with one unit of electricity - and one megawatt of electric energy for cogeneration case (see *Table 5*).

Table 4
CO2 emission rate related to one unit of heat energy for different energy sources ([10])

Steam – 1 GJ production	Natural gas	Extra light oil	Coal
Required quantity (m^3, kg)	32.7	27.1	89.2
Efficiency (%)	90	90	83.0
Calorific value (MJ/m^3, kg)	34	41	13.5
Emission factor (g/MJ)	56.1	77.37	95.1
Oxidation factor	0.995	0.995	0.99
Released CO_2 (t)	0.062	0.086	0.1134

Table 5
CO2 emission rate related to a given unit of heat and one megawatt of electric energy for cogeneration case ([10])

Cogenerated energy (natural gas based)	Steam 5.625 GJ	Electricity 1 MWh
Required quantity (m^3)	331	
Efficiency (%)	50	32
Calorific value (MJ/m^3)	34	
Emission factor (g/MJ)	56.1	
Oxidation factor	0.995	
Released CO_2 (t)	0.628	

Accordingly, in the case of cogeneration the 0.628 t value has to be compared with the 0.97 t value of the coal based electric energy production plus to the 5.625 × 0.1134 t value of the coal based steam production, which practically means a 2.5-fold efficiency!

The comparison is more difficult, if the natural gas based cogeneration has to be compared with the nuclear power plant or power plants using renewable energy sources, considering the fact that their CO_2 emission is zero. In this case cogeneration does not decrease the specific CO_2 emission, on the contrary, it increases the emission (see page 370 of [14]).

Similarly to the energy inputs and production outputs, the CO_2 emissions also can be converted into economic data if we know the market prices. For example at the current market price we have to use 13 EUR/t CO_2 value.

BIBLIOGRAPHY

[1] PETER J NIEWENHUISEN: The global heat is on: preparing for a carbon constrained world – International Energy Solutions - January 2010 (p. 22).

[2] http://ec.europa.eu/environment/climat/climate_action.htm - Accessed at 13th March 2010.

[3] http://ec.europa.eu/climateaction/docs/climate-energy_summary_en.pdf - Accessed at 13th March 2010.

[4] DRUCKER GYÖRGY Mit kívánnak az Egyesült Nemzetek – a globális felmelegedés elleni harc 12 pontja http://www.energiainfo.hu/index.php?par=54&option=news&id=20612.– Accessed at 13th March 2010.

[5] GÁBOR BERCSI: Strategy for the new generation capacity in Hungary – Power-Gen 5th of June 2008 Milan.

[6] Figyelő journal No 2nd and 8th of July 2009 – Building of power plants – Energized (Figyelő 2009. július 2-8. sz. - Erőműépítések – Felvillanyozódtak)

[7] SOREL, S.: JEVONS' paradox revisited: the evidence for backfire from improved energy efficiency (Energy Policy, 37, 4, pp. 1456–1469.) 2009.

[8] TÓTH KLÁRA SZITA: Life cycle analysis, life cycle impact study (Miskolc University Press 2008.) (TÓTHNÉ SZITA KLÁRA: Életciklus elemzés, életciklus hatásértékelés - Miskolci Egyetemi Kiadó 2008.)

[9] Sinergy Kft. Sustainability report 2008 – page 23 (Sinergy Kft. Fenntarthatósági jelentés 2008.)

[10] Table 3, 4 and 5 are prepared by Energy Department of BorsodChem Zrt. on the basis of measurement data of BC-Erőmű Kft.

[11] http://tutor.nok.bme.hu/sandwich/environ/levego.htm - Accessed at 18th April 2009.

[12] Hungarian Electric Energy System Year 2007 statistics (A magyar villamosenergia-rendszer 2007. évi statisztikai adatai).

[13] http://www.gki.hu/hu/individual/tavho.html - Accessed at 18th April 2009.

[14] GERGELY BÜKI: Energy production by cogeneration (Kapcsolt energiatermelés), Budapest, Műegyetemi Kiadó 2007.