ENERGY AND ENVIRONMENT
METHODS TO CALCULATE GREENHOUSE GASES EMISSION

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Abstract **– In this paper we would like to show the current situation in sphere of Energy and Environment. To reduce Greenhouse Gases Emission different organizations formulated many scenarios, which should take into account energy production and consumption in the state for that scenario develops, energy dependence, liberalization of energy sector and diversification of energy sources. To solve some problems it is necessary to study it. To calculate Greenhouse Gas Emissions for any state need to take into account the complexity of the energy system. European Electrical Power, represented by the EURELECTRIC in 2005 has made project Role of Electricity, which contains the formulation of EU energy development scenarios bread in 2050. To solve the problem of power system modeling EUROELECTRIC have been employed a number of institutions that have used two mathematical models: PRIMES model for the period bread in 2030 and PROMETHEUS model bread in target year 2050. In the present paper is described one method to calculation of GHG – program GEMIS. Practical example used in this study is shown for the Czech Republic in accordance with current statistical data and scenarios for future energy sector made up by the Ministry of Industry and Trade of Czech Republic. Equations used in GEMIS and the proposed method had been discussed in this paper.**

Keywords: *climate change, emissions pollutants, environmental impact, greenhouse gas emissions, power system.*

1. INTRODUCTION

In the last decades much attention is drawn energy and environment problem, emissions, energy sustainability and another. Rapid energy production growth leads to environmental impacts which can also constrain development. Energy production, whether from depreciable fossil and nuclear fuels or large – scale exploitation of hydroelectric or biomass resources, leads to many of the most severe environmental impacts faced by developing and industrialized nations alike. These include air pollution, radioactive waste, siltation of river basins, deforestation and soil erosion, etc. In the past, environmental issues have been considered secondary to economic growth in developing and industrialized nations, but now this theme is very important and approved at an extremely vast.

2. PEOPLE AND ENERGY, PREZENT AND FUTURE

Too much CO_2 in our atmosphere is leading to global warming which is causing climate change [1]. The world's leading scientists have warned that unless the rise in average global temperature is kept below 2°C, devastating and irreversible climate change will occur, see fig.1 [2].

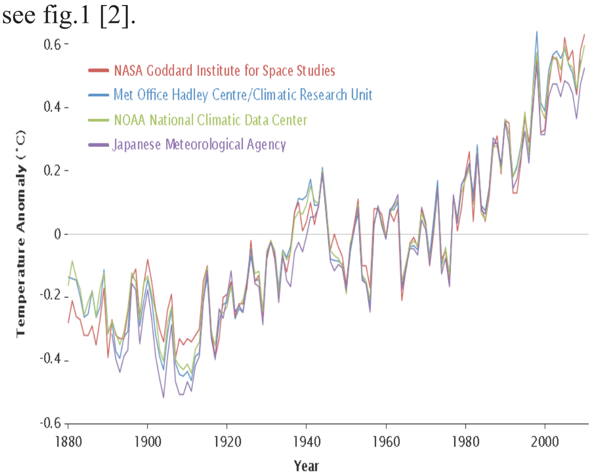

Figure 1: Global surface Temperatures.

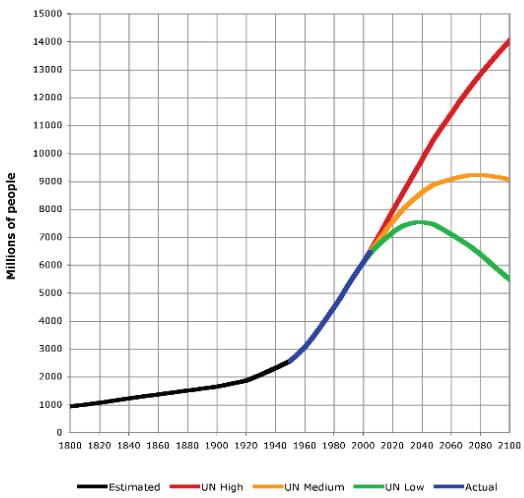

Figure 2: World population 1800 - 2100.

Every day, we use energy and every day we ask for more and with the global population set to rise from 7 to 9 billion by 2050, world energy demand is expected to increase over a next years alone, see fig.2 [3].

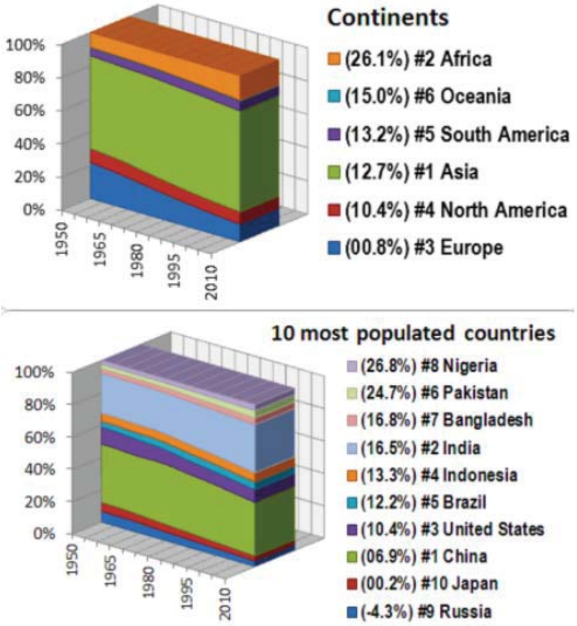

Figure 3: Population evolution in different continents. The vertical axis is logarithmic and is millions of people.

As we can see easily in fig.3 [4], the number of population on the globe during the years 1950 - 2010 declined, according to statistical data and during the years 1950-2010 has increased.

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.

Carbon dioxide (CO2) is the most important anthropogenic GHG. Its annual emissions have grown between 1970 and 2004 by about 80%, from 21 to 38 gigatonnes (Gt), and represented 77% of total anthropogenic GHG emissions in 2004. The rate of growth of CO2-eq emissions was much higher during the recent 10-year period of 1995-2004 (0.92 GtCO2-eq per year) than during the previous period of 1970-1994 (0.43 GtCO2-eq per year)[12].

Fossil fuels still supply 80% of our energy and we emit enormous quantities of CO_2 when we burn them. Today, renewable energies provide only 13% of our energy and this could climb considerable by 2020. But the fact remains fossil fuels will remain our principle source of energy for decades to come, see fig. 4 [5].

Fossil fuel power-plants, heavy industry and refineries are the largest emitters of CO_2, accounting for 52% of global emissions, or around 15 billion tones of CO_2 per year. Therefore these large fixed emitters those need to be most urgently addressed.

In recent years has been an increased focus on energy efficiency and the development of alternative sources of energy, particularly renewable resources but also nuclear and clean coal technologies, such as carbon capture and storage. “Going green” has become the buzzword of the early 2st century. Tend to produce as much electricity on renewable sources is welcome.

Renewable technologies have the ads benefit of not being subject to the price volatility of fossil fuels but may have drawbacks that include intermittent availability and high initial capital costs.

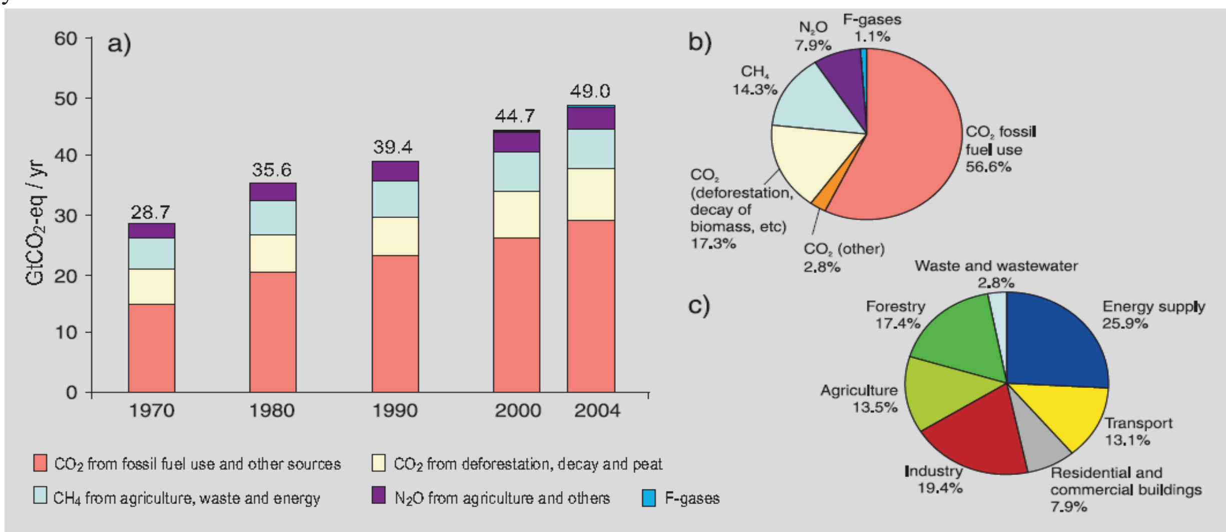

Figure 4. (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.5 (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq.

In January 2007 the European Commission adopted a communication (COM(2007) 1) proposing an energy policy for Europe, with the goal to combat climate change and boost the EU's energy security and competitiveness. This set out the need for the EU to draw up a new energy path towards a more secure, sustainable and low-carbon economy, for the benefit of all users.

One aim is to give energy users greater choice, and another is to spur investment in energy infrastructure. Based on the European Commission's proposal, in March 2007 the Council endorsed the following targets:

- reducing greenhouse gas emissions by at least 20 % (compared with 1990 levels) by 2020;
- improving energy efficiency by 20 % by 2020;
- raising the share of renewable energy to 20 % by 2020;
- increasing the level of bio fuels in transport fuel to 10 % by 2020.

The use of renewable energy sources is seen as a key element in energy policy, reducing the dependence on fuel from nonmember countries, reducing emissions from carbon sources, and decoupling energy costs from oil prices. The second key element is constraining demand, by promoting energy efficiency both within the energy sector itself and at end-use.

In order to meet the increasing requirements of policy makers for energy monitoring, Eurostat has developed a coherent and harmonized system of energy statistics. Annual data collection covers the 27 Member States of the EU, the candidate countries of Croatia and Turkey, and the European Economic Area countries of Iceland and Norway; time-series run back to 1985 for some countries, but are more generally available from 1990.

3. THE METHODOLOGY OF MODELING ELEMENTS AND COMPONENTS OF ENERGY GRIDS

During the current possibilities of technologies taking into account the numerical stability and accuracy of identifying restricted real physical model parameters for each specific problem, you must create a model designed for solving certain types of tasks[6].

In general the steps of modeling a power system or for problems decision can be listed as a, see fig. 5.

When choosing a mathematical model is necessary to choose the model that is as simple as possible, while respecting all relevant variables and dependencies for the group to solve transient or steady action. Depending on the issue approved, shall be elected and the mathematical model, which differs from case to case.

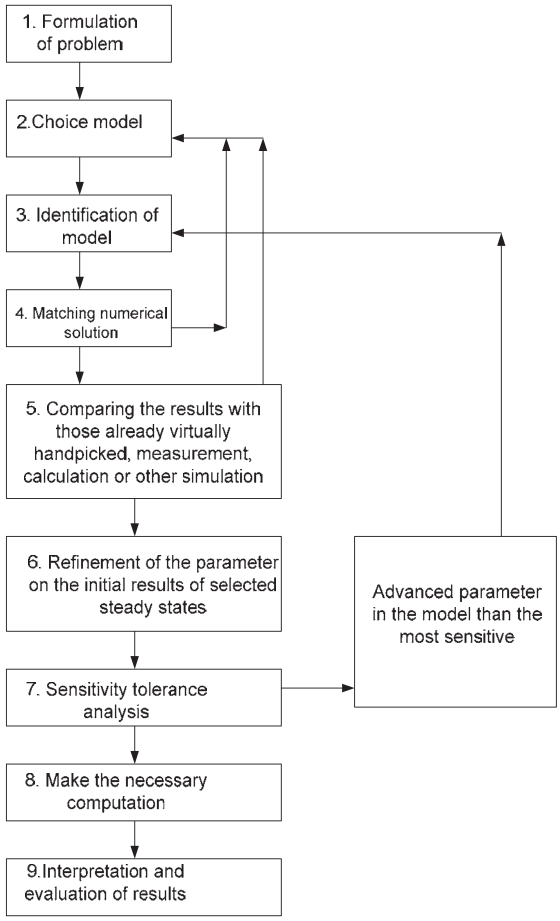

Figure 5: The steps of modeling a power system.

Every step in the method of calculation shown in fig. 5 has its importance, and each of them have some variations and complications.

3.1. A methods for calculating greenhouse gas emissions

Next in this work we would like to find a method for calculating greenhouse gas emissions.

The problem of greenhouse gas calculation is studied in most countries of the world. There are various methods and programs for calculating these emissions, such as GEMIS, MARKAL, EMPEB etc. Of course all these methods are good and can be used.

For each of the impacts considered, environmental controls in the form of regulations can be applied to reduce environmental discharges or other effects. The type of regulation depends on the evaluated impact. Table 1 lists the regulatory options available for each impact [7].

The regulations can be imposed singly or in combinations. It is possible to designate regulations that will apply only to specified facilities, specified types of facilities, in designated geographical areas, after a specified starting date, or to new, existing, or all facilities.

IMPACT	REGULATIONS AVAILABLE
Air Pollution	•Emission limits •Required control device •Chemical content of fuel
Water Supply and Pollution	•Water intake limit •Wastewater volume discharge limit •Pollutant concentration •Required equipment •Chemical content of fuel
Land Use	•Land use restriction •Land restoration requirement
Solid Waste	•Waste quantity limit •Required control technique •Chemical content of fuel
Occupational Health and Safety	•Required control program
Resources	Not applicable

Table 1: A lists the regulatory options available for each impact.

This gives the user flexibility to apply different regulatory control programs.

The proposed basic equation, using air pollution as an example is as below[7]:

$$UEM_1 = UEM_1 \cdot E_{INPUT} \quad (1)$$

where:

UEM_i -Uncontrolled emissions of Pollutant i (kg/year),

UEF_i - Emission Factor for Pollutant i (kg/GJ_{in}),

E_{input} - Energy Input (GJ).

In general, an emission factor is dependent on the fuel used except SO_2 [8]. For SO_2 emission factor has the form:

$$EF_{SO_2} = 2C_S(1-\alpha_S)\frac{1}{H_U}10^6(1-\beta) \quad (2)$$

where:

• EF_{SO2} - specific emission factor;

• C_S - sulfur content in fuel, %;

• α_S - sulfur content in the ashes;

• H_u - heat capacity of gas;

• A century - the efficiency of secondary reduction in%;

• β - the possibility to provide secondary measures, in%.

Calculation methodology of the emission [7], one determined the following values and constrains:

$$C_m = C_V \cdot \frac{22.4}{M_{pol}} \cdot \frac{273.5 + t}{293.15} \cdot\cdot \frac{1.013 \cdot 10^5}{p_b} \quad \left[{}^{mg}/_{m^3N}\right] \quad (3)$$

where:

Cm - mass concentration of the pollutant, in ppm,

Cv - volumetric concentration of the pollutant, in mg/m^3N

Mpol - molar mass of the pollutant, in kg/kmol,

22,4l - molar volume under normal conditions, in m3/kmol,

t - temperature, °C

p_b - barometric pressure, in Pa.

Thus the mean value becomes:

$$[(C_m)_{med}]_i = \frac{\sum_{i=1}^{n}(C_m)_i}{n} \quad \left[{}^{mg}/_{m^3N}\right] \quad (4)$$

where:

n - is the simultaneous registered traffic values,

i – specie of the pollutant.

Emission factors and emission inventories have long been fundamental tools for air quality management. Emission estimates are important for developing emission control strategies, determining applicability of permitting and control programs, ascertaining the effects of sources and appropriate mitigation strategies, and a number of other related applications by an array of users, including federal, state, and local agencies, consultants, and industry. Data from specific source of emission tests or continuous emission monitors are usually preferred to estimating a source's emissions because those data provide the best representation of the tested source's emissions. However, test data from individual sources are not always available and/or they may not reflect the variability of actual emissions over time. Thus, emission factors are frequently the best or only method available for estimating emissions, in spite of their limitations.

Emission factors may be appropriate to use in a number of situations such as making specific source emission estimates for area wide inventories. These inventories have many purposes including ambient dispersion modeling and analysis, control strategy development, and in screening sources for compliance investigations. Use of emission factor may also be appropriate in some permitting applications, such as in applicability determinations and in establishing operating permit fees.

3.2. GEMIS

Another method for calculating greenhouse gas emissions is GEMIS method [9].

GEMIS (Global Emission Model for Integrated Systems) is a computerized life-cycle analysis model, LCA database, and cost-emission analysis system. GEMIS evaluates environmental impacts of energy, material and transport systems, i. e. air emissions (SO_2, NO_x, particulates, CO, NMVOC etc.), greenhouse gases (CO_2, CH_4, N_2O etc.), solid/liquid wastes, and land use. It can be used to analyze local, regional, national and global energy/material/transport systems, or

any scope of sectoral or cross-spectral sub-system (e.g., a plant, facility, or special life-cycle). Furthermore, GEMIS can determine the economic costs of scenario options.
The combustion calculation in GEMIS uses the physico-chemical attributes of fuels (see chemical constants) and a series of terms to calculate

- the effective reduction rate,
- the emission concentration, and
- the emission factor.

From the process data, GEMIS can compute further values:
hourly emission = hourly flue-gas volume * clean gas concentration;
annual emission = hourly emission * annual operating time;
emission $factor_{input\text{-}based}$ = hourly emission / hourly fuel consumption;
emission $factor_{output\text{-}based}$ = emission $factor_{input\text{-}based}$ / η.
Program GEMIS is linear, it is worth looking quantities x_1 counts type equations[10]:

$$x_1 = f_k(y_j) = y_{kj} y_j + k_{k0} \tag{5}$$

where
f_k (y_j) is a linear function, and input variables y_j, k_{kj}, k_{ko} constants.
For example the emissions of a substance during combustion of fuel E_J compute GEMIS of relation:

$$E_J = k_j \cdot Q \tag{6}$$

where:
k_j so-called emission factor,
Q is the heat in the process of bringing fuel.
The emission factor kj are either stored in a data file or are computed. The size issue can be further adjusted for specific conditions such as the concentration of solid particles in the exhaust gas can be adjusted by the effectiveness of dust separators. The advantage of linear algorithms of the program is to simplify and speed up the computation, as each individual process chain can easily superimpose. This solution represents a certain compromise between calculation accuracy and the benefits to the user.

3.3. Practical example of use of the program GEMIS

Next, we intend to analyze greenhouse gas emissions with linear program GEMIS used for the Czech Republic.
In the next ten-fifteen years, expected in absolute values should increase installed capacity of renewable energy, especially wind and solar power. From these sources is expected, according to some opinions, increasing installed capacity more than 40GW [11].

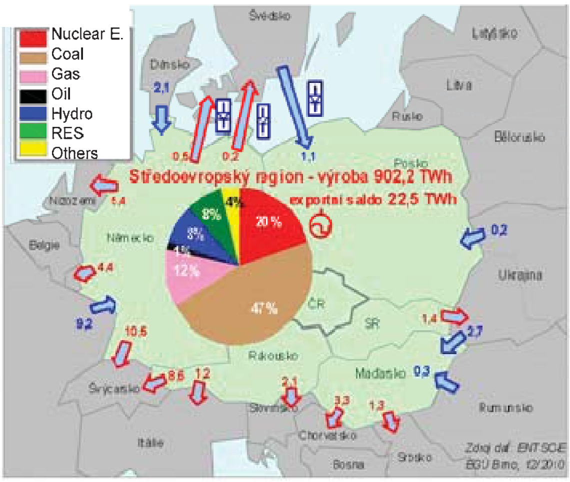

Figure 6: Electricity transmission interstate Profile Central European (2009).

The Energetic sector in the middle Europe region has a great influence of power Germany power system, according to the latest events that took place Fokushima nuclear station in Japan, many of the German nuclear stations were temporarily closed. If their renewal and construction of new blocks, the energy produced in the nuclear industry will increase considerably. Another group of sources, which are expected to increase output by more than 17 GW, the gas station. The situation in the Central region in 2015 figure 7 describes.

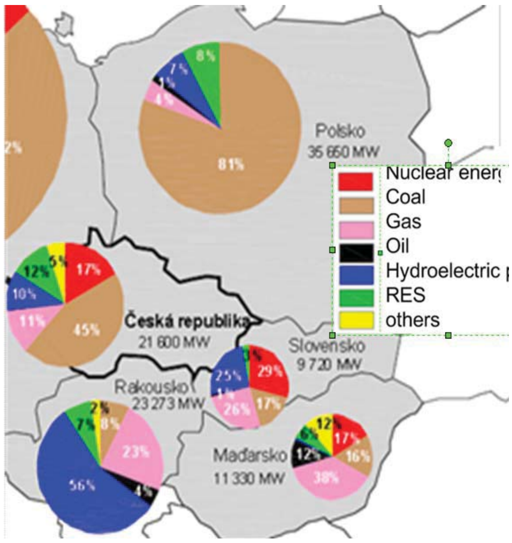

Figure 7: Estimated structure mounted power in Central Europe in 2015.

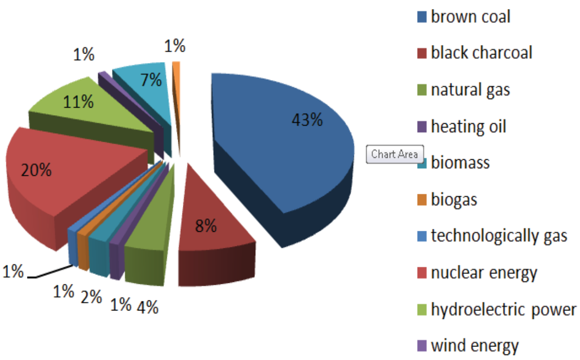

Figure 8: Current structure mounted power sources for CR by primary sources (end 2010) [MW%].

In the following text we will show three different cases of the energy mix for the Czech Republic. In fig.8 are indicate the current structure mounted power sources for Czech Republic by primary sources.

In figure 9 is shown the energy mix in the Czech Republic for the reference period it is mean the current period.

Selected option 1 MIX CR 2010

Energy | Materials | Persons | Freight | Residue | Money

Energy source	[GWh]
gas-CC-CZ-OT-ZP	1E+3
hydro power plant-without pumping-CEZ	4E+3
lignite-ST-CZ-HU 4x200	5E+4
nuclear-ST-CZ-Dukovany	1.4E+4
nuclear-ST-CZ-Temelín	1.3E+4
solar-PV-amorph-framed-DE-2000	1E+3
wind mill-CZ	1E+3
wood-cogen-CZ-ORC th	1.5E+3
Sum	8.55E+4

Figure 9: The energy mix in the Czech Republic for the reference period.

Selected option 2 MIX CR 2020 - I

Energy | Materials | Persons | Freight | Residue | Money

Energy source	[GWh]
biogas-manure-ICE-500-DE-2005-th/en	1E+3
solar-PV-amorph-framed-DE-2005 (1000)	2E+3
wind mill-CZ	1.5E+3
hydro power plant-without pumping-CEZ	5E+3
wood-cogen-CZ-ORC th	1E+3
gas-CC-CZ-ZP	5E+3
lignite-ST-CZ-new HU	1.8E+4
lignite-ST-CZ-HU 4x200	1.5E+4
nuclear-powerplant-PWR-FR-2010 (EPR)	1E+4
nuclear-ST-CZ-Dukovany	1.4E+4
nuclear-ST-CZ-Temelín	1.4E+4
Sum	8.65E+4

Figure 10: The energy mix I in the Czech Republic for first scenario.

These two mixes are calculated taking into account the energy strategies as developed by the Ministry of Industry and Trade of the Czech Republic. In first MIX I percentage increases electrical energy produced on nuclear energy, see fig. 10, and MIX-II we calculate a greenhouse emissions focused on renewable energy, fig. 11.

Selected option 3 MIX CR 2020 - II

Energy | Materials | Persons | Freight | Residue | Money

Energy source	[GWh]
hydro power plant-without pumping-CEZ	5E+3
nuclear-ST-CZ-Temelín	1.5E+4
nuclear-ST-CZ-Dukovany	1.4E+4
nuclear-powerplant-PWR-FR-2010 (EPR)	0
lignite-ST-CZ-new HU	2E+4
lignite-ST-CZ-HU 4x200	1.8E+4
solar-PV-amorph-framed-DE-2005 (1000)	1.5E+3
wind mill-CZ	1.5E+3
wood-cogen-CZ-ORC th	1E+3
gas-CC-CZ-ZP	1E+4
biogas-manure-ICE-500-DE-2005-th/en	5E+2
Sum	8.65E+4

Figure 11: The energy mix II in the Czech Republic for second scenario.

Next we analyze the difference in greenhouse gas emissions in these three cases. I got the idea that case power consumption to be the same, see fig. 12, just different proportions to be used in types of energy, ultimately resulting emissions will be lower than in the current period.

#	Options	Energy demand [GWh]
1	MIX CR 2010	8.55E+4
2	MIX CR 2020 - I	8.65E+4
3	MIX CR 2020 - II	8.65E+4

Figure 12: The current situation of power system in Czech Republic.

The most important parameter is the reference value of CO_2 equivalent. Since, as already explained, has a different emissivity of greenhouse gases, so called from absorb or emit radiation in varying degrees. The resulting effect on the greenhouse effect therefore depends on the ability of gas adsorptions capacity of thermal radiation and the "life time" of gas in the atmosphere.

Option [kg]	CO2 equivalent	CO2	CH4	N2O
MIX CR 2010	6.09786E+10	6.01994E+10	1.0738E+7	1.77926E+6
MIX CR 2020 - I	3.8361E+10	3.76224E+10	1.67557E+7	1.15481E+6
MIX CR 2020 - II	4.59892E+10	4.49833E+10	2.52787E+7	1.40543E+6

Figure 13: The results of GHE for three variants.

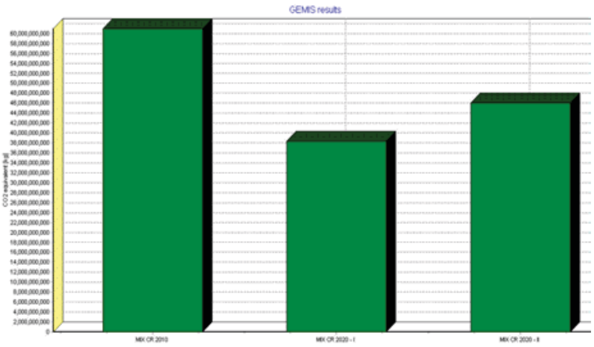

Figure 14: Graph comparing between three energy mix in the Czech Republic for CO_2 equivalent output sizes.

So to a simple way to express the total effect of greenhouse gases emitted in the analysis process for warming the air, introducing the so-called CO_2 equivalents, the graph results of comparing the CO_2 equivalent output size of ours scenarios we can see in fig. 13 and fig. 14.

The expected scenario options for the future amount of greenhouse gas emissions is considerably smaller compared with the energy mix in the Czech Republic for the reference period.

Results: Liquid wastes

Scope: local / all other / total

Option [kg]	P	N	AOX	COD	BOD5	inorg. salt
MIX CR 2010	3.33356E-1	1.99383E+1	3.97427E-1	1.56113E+6	4.42262E+4	1.74048E+6
MIX CR 2020 - I	2.01808	1.18875E+2	5.41014E-1	1.63354E+6	4.67134E+4	3.48464E+6
MIX CR 2020 - II	1.27643	7.5341E+1	5.19753E-1	1.74139E+6	4.95107E+4	2.61273E+6

Figure 15: The results of liquid wasters for three variants.

Results: Employment effects

Scope: local / all other / total

Option [person years]	direct employment effects	employment effects through investment	operationally employment effects Fixed costs	operationally employment effects Variable costs	Total employment effects
MIX CR 2010	1.87361E+4	4.25885E+3	2.33142E+4	7.75164E+3	5.40608E+4
MIX CR 2020 - I	1.32846E+4	8.11599E+3	2.75812E+4	1.15258E+4	6.05077E+4
MIX CR 2020 - II	1.45052E+4	7.02535E+3	2.35683E+4	1.36785E+4	5.87774E+4

Figure 16: Employment effects for three variants.

The program GEMIS also can make some economic calculations, see figure 15.

GEMIS calculates the annual costs of processes based on the investment costs, multiplied by the annuity factor f [9].

The annuity factor f is derived from the following term:

$$f = z \cdot \frac{(1+z)^t}{[(1+z)^t - 1]} \qquad (7)$$

where:

z = discount rate (in decimals, e.g. 8% = 0.08);
t = lifetime in years (= time horizon).

In GEMIS, a simplified calculation of the costs for the delivery of a product by a process is included. For this, the following cost elements are used:

- Investment costs are derived by multiplying the specific investment costs with the power of the process. If emission reduction technologies are linked to the process (possible for combustion processes), their respective investment costs are included also (scaled automatically to the power of the process).
- The annual costs of the investment are derived using the annuity method.
- The fixed annual costs are derived by multiplying the specific fixed costs with the power of the process. If emission reduction technologies are linked to the process (possible for combustion processes), their respective fixed costs are included also (scaled automatically to the power of the process).
- Variable non-fuel costs are derived by multiplying the specific value with the power of the process and the annual operating time (full-load equivalents).
- The fuel or input product costs are derived by multiplying the annual fuel use (from power, efficiency, and annual operating time) and the specific fuel or product costs. The specific fuel/product costs can either be taken from the product database, or can be entered by the user as a process-specific value.

Results: Costs

Scope: local / all other / total

Option [€]	Internal costs	External Costs	Internal + external costs
MIX CR 2010	3.22451E+9	2.36999E+9	5.5945E+9
MIX CR 2020 - I	4.29233E+9	1.82631E+9	6.11864E+9
MIX CR 2020 - II	4.14861E+9	1.87175E+9	6.02036E+9

Figure 17: The results of liquid wasters for three variants.

In Fig.17 and Fig.18 are shown some of the possibilities of the program GEMIS.

Turnover of all processes

Process	Product	Unit	MIX CR 2010
biogas (double cropping)-ICE-cogen 500-	electricity	GWh	3.46723E-7
biogas (double-cropping)-ICE-cogen 500-	electricity	GWh	1.04147E-6
biogas (double-cropping)-ICE-cogen 500-	electricity	GWh	9.26523E-9
biogas-biowastes-ICE-cogen 500-2010/g	electricity	GWh	2.18558E-6
biogas-biowastes-ICE-cogen 500-2020/g	electricity	GWh	1.73362E-7
biogas-biowastes-ICE-cogen 500-2030/g	electricity	GWh	3.8914E-9
biogas-input-mix-C+C+SB-2005	manure-coferme	GWh	4.52226E-4
biogas-input-mix-C+P-2000	manure-coferme	GWh	6.40774E-5
biogas-maize-ICE-cogen 500-0xCat-2005	electricity	GWh	1.02437E-5
biogas-maize-ICE-cogen 500-0xCat-2010	electricity	GWh	4.71553E-6
biogas-maize-ICE-cogen 500-0xCat-2020	electricity	GWh	3.46723E-7
biogas-maize-ICE-cogen 500-0xCat-2030	electricity	GWh	4.63262E-9
biogas-manure-1500-ICE-cogen 500-0xC	electricity	GWh	1.0417E-5
biogas-manure-ICE-500-DE-2005/gross	electricity	GWh	1.11701E-4
biogas-manure-ICE-500-DE-2005-th/en	warm water	GWh	0
biogas-manure-ICE-cogen 500-0xCat-202	electricity	GWh	8.66808E-7
biogas-manure-ICE-cogen 500-0xCat-203	electricity	GWh	4.63262E-9
biomass-ST-EU-2010	electricity	GWh	7.82982E-5
biomass-ST-EU-2020	electricity	GWh	1.67224E-6
biomass-ST-EU-2030	electricity	GWh	1.36934E-1
biowastegas-ICE-cogen-lean-250-intern	warm water	GWh	8.31686E-7
blast-furnace-gas-GT-DE-2005	electricity	GWh	2.88194E-4
blasting (ANFO)	explosives	kg	6.21454E+5
bonus-electricity-bimass-no emission-CZ	electricity from b	GWh	-3.21429E+2
bonus-gas-heating-CZ	bonus for heat fr	GWh	-1.21633E-4
bonus-heat-no emission-CZ	bonus for heat fr	GWh	-4.3021E+3
bonus-municipal waste-CZ	bonus for waste-	GWh	-4.86533E-4
CaO-pulverized-CZ	limestone grinde	kg	8.03577E+6
cement-plant-CZ	cement	kg	8.65244E+8
chem-inorg\aluminium fluoride-generic	aluminium fluorid	kg	3.35295E+4
chem-inorg\aluminium oxide-mix-DE-2000	bauxite	kg	1.16796E+6
chem-inorg\aluminium oxide-mix-DE-2005	bauxite	kg	7.72228

Figure 18: Turnover for all processes.

4. CONCLUSIONS

At the end of this article we want to say that one of the biggest tasks of our generation is to leave for posterity a clean environment. Ministries, scientists elaborate scenarios for reducing greenhouse gas emissions, ways to capture carbon dioxide. But we have to take into account the fact that much depends on us - electricity users. Electricity can be saved at various levels: production, transmission, distribution system consumers which means saving electricity in households.

In terms of energy savings, there are several possible ways to implement them. One of them is to use economical light sources, most economical household appliances and new customers to be more economical.

The environment has no borders and is not infinite, so you must keep it and do not forget about it.

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