EIE/06/221/SI2.442663

REPORT

Work Package 06:

Benchmarking for increasing biogas injection.

Deliverable D20

Estimation of the potential for increasing the use of biogas for heating and cooling when using the best practises in the partners countries; extrapolation EU-wide

Responsible partner:

Energy Agency of Vysocina

Zbyněk Bouda

Date:

December 2008

Contents

Contents **2**

Figure list **3**

Table list **4**

1. Abstract **5**

2. Introduction to the topic **7**

Indicative targets of the EU member states 9

3. Term definition and the potential stating methods **10**

Theoretical potential 10

Main sources and features of the biomass 10

Technological (available) potential 21

Factors determining the utilization of the potential 21

Economically available potential 21

Cost of investments 22

4. Economic tools for evaluating the projects **23**

Basic principles for the economical evaluation of the projects 24

Aspects of the economical evaluation of the energy projects 24

Procedure of the economical evaluation 26

5. Estimation of the potential for increasing the use of biogas when using the best practices **29**

Example 1 - economic conditions when using the current practices 39

Example 2 - economic conditions when using the best practices 41

6. Conclusion **43**

7. Literature **44**

Figure list

Figure 1: Indicative targets of the EU member states in the sector of power generation until 2010 from OZE 9

Figure 2: Proportion of the particular input materials in the total potential (EU27) 18

Figure 3: Total potential of the power generation from biogas for the invidual EU countries.. 19

Figure 4: Potential of the power generation from biogas showing the particular resources for the individual EU countries 20

Figure 5: Graph – the potential of supplied energy in the EU countries for as a bp 31

Figure 6: Graph – The comparison of the saved air pollutant emissions – actual state and the best practice state...38

Table list

Table 1: The source data for the calculation of the theoretical potential 12

Table 2: The source data for stating the theoretical potencial 14

Table 3: Features of the inputs 15

Table 4: Theoretical potential 17

Table 5: The potential of supplied energy in the EU countries for as a bp..........................30

Table 6: Tab – the saved air pollutant emissions – actual state 32

Table 7: Tab – the saved air pollutant emissions – best practices 34

Table 8: Tab – The comparison of the saved air pollutant emissions – actual state and the best practice state..36

1. Abstract

This document shows the possibilities of increasing the energy generation from renewable resources, in our case by generating biogas from the biodegradable material.

In the first part there is a calculation of the potencial of the energy generated from biogas for the particular member states.

The most important biomass resources for the production of biogas are:

1. fytomass with a high content of lignocelulose,
2. fytomass from oil-containing crop-plants,
3. fytomass with a high content of amyl and sacharids,
4. biological trash and by-products of animal origin,
5. mixtures of different types of organic trash.

<u>Possible main resource areas:</u>

agriculture – this is where the majority of the residual biomass is originates from,

- waste from the stock keeping (ejecta of livestock)
- rests from the plant production which can´t find any other utilization:
  - Plant residues from the agricultural first-production an landkeeping: corn and grain straw, colza straw, residues from grassfields and grazing lands, rests after bush cutting and forrest clearing, waste from orchards and vinyards.
  - Waste from stock keeping: ejecta of livestock, surplus feedstuff, waste from the dairy farms, waste from the connected processing plants.
  - Municipal biological waste from countryside housing areas: sludge from sewage water, biological parts of the solid municipal waste, biological rests from the maintanance of public greenery.
- Resp. a targeted non-food-processing plant production
- grass fytomass from additionally maintained grassfields which needs to be removed constantly

• municipal area

- biological waste which makes about 40% of the municipal waste
- residues from the maintenance of the greenery and the sludge from the sewage works

Biodegradable waste from the industrial area

- biological waste from the food-processing industry and other industries
- waste from the plant processing and storing works
- waste from abattoirs
- waste from dairy factories
- waste from destilleries
- waste from canning factories
- waste from wineries
- waste from bakeries

On the basis of statistic figures a theoretical potential of the biogas production in each EU member country was stated.

For the 27 EU countries this potential is 2 105 PJ.a-1 (petajoul per year)

Other parts of the study focus on the way of calculating and stating the technologically and economically available potential.

A simple tool in the form an Excell sheet was created for the calculation of the basic parameters for the investments decisions, being part of this study.

2. Introduction to the topic

An analysis of available energy potential from the biogas was made on the base of available facts and model calculations ensuring that the final figures are as close to the actual state as possible. Biomass as a real and also potential energy source experiences a tremendous boom at the moment. The issue of using biomass as a renewable energy source is being discussed (unfortunately often also uncritically) in all media´s and is a part of every project about the issue of renewable energy resources.

The truth is that Europe has an indispensable potential of the biomass energy, of which the real utility is varies depending on the particular region. There are areas where the biomass has been used to up to 80 % of the current potential, and on the other hand there are areas where people are just beginning using the biomass.

On the other hand we must see that the biomass is capable of helping to solve the satisfying of energy needs on the level of regions, but it is in no case capable of covering the energy needs of the bigger part of the regions in a complex way.

Everywhere in the world hope is put into the biomass as an alternative and renewable energy source. It´s supposed to replace a substantial part of the disappearing non-renewable classical energy resources in the future like coal, oil and natural gas. In the strict sense of the word the biomass is a biological mass of plant origin gained on the basis of the fotosyntetic conversion of the solar energy. It is more appropriate though to define biomass as a substance of biological origin which includes the plant originated biomass as well as the animal originated biomass. Biomass that is used for the energy generating purposes is either gained intentionally as a result of production activity, or it is a residue of the agricultural, food-processing or forestry activities, or it is a residue of the community management, maintanace and country keeping.

The estimated worldwide production of energetically utilizable biomass is almost ten times higher in its energy potencial than the annual volume of the world oil and natural gas production. Still is the proportion of the renewable energy resources to which the biomass also belongs, in the whole energy consumption quite small. For example in 15 countries of the EU this proportion makes about 5%, with Austria, Sweden, Finland and Portugal being at the top with 14 - 18% utilizable energy from the biomass. All the more significantly will the bioenergy sector develop in the next years, as the EU countries declared a goal to provide 10% of the whole energy consumption from biomass until 2010.

The statistics of the biogass shows the increasing importance of this sector from the aspect of for example generating renewable energy. In 2006 in sum 17,3 TWh (this is 17,3 billions of kWh) of electricity were generated from biogas, sludge gas and dump gas in the frame of the EU countries. (Comparing with 2005 shows a strong annual increase in the power generation of about plus 29 % (13,4 TWh on the whole in 2005). The actual power generation from biogas amounts about 40 % of the whole 17,3 TWh production and we can expect this rate to further rise.

The contribution of biogas plants illustrates the evolvement in Germany. Thanks to a well created system of subsidies the sector of biogass experienced the biggest expansion ever in 2006; in sum 700 new works were opened with the total supply of 550MWel. The total number of biogas plants in Germany in 2006 is estimated to reach 3.500. Their general installed power supply has already reached 1.100 MWel with the production of more than 5TWh of power. After taking the works from 2006 to full performance and with the new installations the full productivity in 2007 was expected to reach more than 10 TWh. The reality will probably be different according to the significant increase of the prices of the agricultural commodities. An interesting illustration of the effectivity of the electricity in biogas plants is the presumption published in Germany which says that a recently installed performance of 550 MWel in biogas is thank to its much higher stability of the power generation able to provide a comparable power productivity as generated by 2 280 MWel of the newly installed wind power stations in 2006. Biogas constantly shows its increasing importance in the energy management and in the future „energy mix“.

Other interesting „biogas country“ is for example Austria. A significant expansion of biogas plants took place between 2001 – 2005, when at the end of 2005 the total number of plants was 300 and the installed power performance reached 80 MWel. The annual power production reached 570 GWh, which is a volume that equals an annual consumption of 160 000 households.

Well implemented biogas plants (further „BP“) are modern and environmentally friendly plants which are commonly run throughout the whole European Union. They process a wide variety of materials or types of waste of biological origin by way of the anaerobic digestion with no access of air in closed reactors. The result of the process is biogas which is so far mostly used for an efficient generation of renewable electricity and heat, and also the digestate which can be used as an effective fertilizer (similar to compost).

Indicative targets for the proportion of Of OZE for the particular member states is based on the regulation 2001/77/EC about the subsidy of electricity from OZE on the internal electricity market in the EU. They are defined as percentual proportions of the power generation of the bruto domestic power consumption in each member state. The regulation also defines the general target for the European Community which is 22,1%.

The regulation obligs the member states to take steps and programs of subvention that will lead to increasing the power generation from renewable resources. The specific form of the steps is up to the decision of the particular states, but they must conform with the regulations for the internal electricity market and be adequate to the indicative targets, so they lead to their fulfilling in 2010.

Indicative targets of the EU member states

Currently there are only the summary data of power generation for the year 2006 from OZE available.

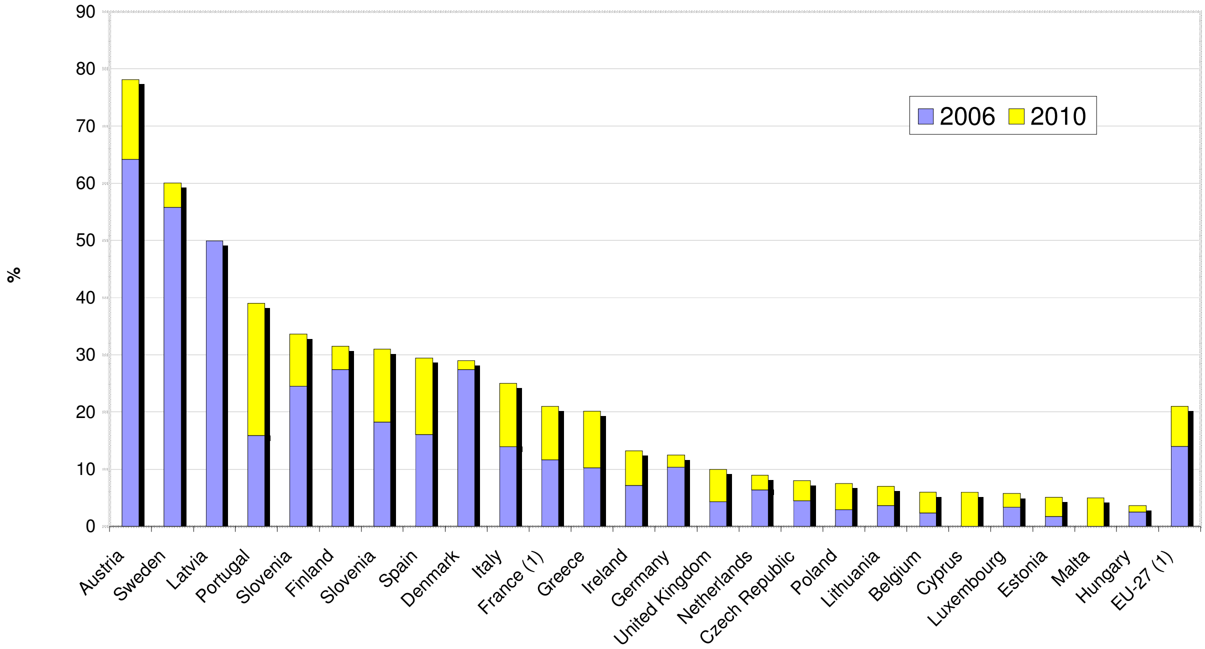

Figure 1: **Indicative targets of the EU member states in the sector of power generation until 2010 from OZE**

3. Term definition and the potential stating methods

Theoretical potential

Theoretical potenatial is such energy potential that is based on the total quantity of resources available. It includes all resources available for the biogas production which include mainly products and waste of agriculture, biodegradable waste from industrial production and the biodegradable part of the municipal waste.

In this study we result from the statistical figures for the EU countries (EUROSTAT). The basic records used are the information concerning the extent of the agriculturally utilizable land, the number of livestock, the number of inhabitants, volume of the waste produced in particular member countries. The records concerning the number of livestock are converted to livestock units.

Main sources and features of the biomass

We can devide the energy biomass into 5 basic groups:

1. fytomass with a high content of lignocelulose,
2. fytomass from oil-containing crop-plants,
3. fytomass with a high content of amyl and sacharids,
4. biological trash and by-products of animal origin,
5. mixtures of different types of organic trash

Possible main source areas:

agriculture – this is where the majority of the residual biomass is created,

Possible main resource areas:

agriculture – this is where the majority of the residual biomass is originates from,

- waste from the stock keeping (ejecta of livestock)
- rests from the plant production which can´t find any other utilization:
    - Plant residues from the agricultural first-production an landkeeping: corn and grain straw, colza straw, residues from grassfields and grazing lands, rests after bush cutting and forrest clearing, waste from orchards and vinyards.
    - Waste from stock keeping: ejecta of livestock, surplus feedstuff, waste from the dairy farms, waste from the connected processing plants.

- Municipal biological waste from countryside housing areas: sludge from sewage water, biological parts of the solid municipal waste, biological rests from the maintanance of public greenery.

- Resp. a targeted non-food-processing plant production
- grass fytomass from additionally maintained grassfields which needs to be removed constantly

• municipal area

- – biological waste which makes about 40% of the municipal waste
- – residues from the maintenance of the greenery and the sludge from the sewage works

Biodegradable waste from the industrial area

- biological waste from the food-processing industry and other industries
- waste from the plant processing and storing works
- waste from abattoirs
- waste from dairy factories
- waste from destilleries
- waste from canning factories
- waste from wineries
- waste from bakeries

Table 1: The source data for the calculation of the theoretical potential

	Total population	Utilised agricultural area	Municipal waste	Industrial waste
	(million)	(1 000 ha)	(kg per capita)	(1 000 t)
Belgium	11	1 382	475	0
Bulgaria	8	5 190	446	175
Czech Republic	10	3 566	296	433
Denmark	5	2 717	737	1 474
Germany	82	17 038	566	8 563
Estonia	1	764	466	181
Ireland	4	4 305	804	284
Greece	11	3 254	443	294
Spain	44	25 383	583	2 955
France (1)	63	29 584	553	12 381
Italy	59	14 710	548	7 875
Cyprus	1	159	745	6
Latvia	2	1 734	411	17
Lithuania	3	2 791	390	88
Luxembourg	1	129	702	0
Hungary	10	5 827	468	495
Malta	0	10	652	3
Netherlands	16	1 923	625	4 025
Austria	8	3 240	617	4 233
Poland	38	15 941	259	2 266
Portugal	11	3 767	435	1 554
Romania	22	14 270	385	429
Slovenia	2	490	432	3
Slovakia	5	1 939	301	189
Finland	5	2 294	488	3 933
Sweden	9	3 187	497	6 626
United Kingdom	61	16 761	588	10 032
EU-27 (1)	495	182 357	517	68 514

When stating the potential we convert the produce of biological waste by different stock types to one BLU (big livestock unit) which equals to one piece of adult cattle. The coeficients for the BLU conversion are 0,3 for pigs; 0,1 for sheep; 0,0026 for poultry. The average produce of one BLU is 0,708 m3 per day, while the average heating power of biogas is 20,5 MJ/m^3.

Table 2: The source data for stating the theoretical potencial

	Number of pigs	Number of dairy cows	Number of cattle	Number of sheep	BLU
	(thousand)	(thousand)	(thousand)	(thousand)	(thousand)
Belgium	6 200	524	2 573		4 443
Bulgaria	889	336	611	1 526	1 244
Czech Republic	2 662	407	1 367	184	2 318
Denmark	13 170	551	1 545	98	5 748
Germany	27 113	4 087	12 707	1 926	22 580
Estonia	375	104	242	74	418
Ireland	1 575	1 088	5 902	3 531	6 635
Greece	1 038	150	682	8 984	1 905
Spain	26 061	903	6 585	22 194	16 209
France (1)	14 968	3 759	19 124	8 285	24 376
Italy	9 273	1 839	6 577	8 237	10 706
Cyprus	472	24	56	292	239
Latvia	414	180	399	54	629
Lithuania	923	405	788	43	1 316
Luxembourg	86	40	193	8	221
Hungary	3 871	266	705	1 232	2 115
Malta	77	8	19	12	47
Netherlands	11 710	1 490	3 820	1 715	8 231
Austria	3 286	525	2 000	351	3 146
Poland	17 621	2 677	5 406	316	12 320
Portugal	2 374	306	1 443	3 365	2 509
Romania	6 565	1 573	2 819	8 469	6 644
Slovenia	543	116	480	131	676
Slovakia	952	180	502	347	902
Finland	1 427	296	903	90	1 455
Sweden	1 728	366	1 517	521	2 149
United Kingdom	4 674	1 978	10 078	23 723	13 815
EU-27 (1)	160 046	24 177	89 042	95 709	152 995

The potencial for power generation is calculated on the basis of records about the biogass production that are available from the sources mentioned. The production data used are summed up in the following chart:

Table 3: Features of the inputs

Material	Contents of solids	Contents of the biological solids in the solids	Gas yield	Contents of CH4	Contents of N in the solids	Contents of NH4 in the solids	Contents of P in the solids
	[%]	[%]	[Nm^3/t]	[%]	[%]	[%]	[%]
Natural fertilizers							
Beef slurr	8-11	75-82	200-500	60	2,6-6,7	1-4	0,5-3,3
Pork slurr	7	75-86	300-700	60-70	6-18	3-17	2-10
Beef manure	25	68-76	210-300	60	1,1-3,4	0,22-2	1-1,5
Pork manure	20-25	75-80	270-450	60	2,6-5,2	0,9-1,8	2,3-2,8
Poultry manure	32	63-80	250-450	60	5,4	0,39	- - -
Renewable sources							
Corn silage	20-35	85-95	450-700	50-55	1,1-2	0,15-0,3	0,2-0,3
Rye (GPS-?)	30-35	92-98	550-680	55	4	0,57	0,71
Sugarbeet	23	90-95	800-860	53-54	2,6	0,2	0,4
Beet	12	75-85	620-850	53-54	1,9	0,3-0,4	0,3-0,4
Beet leaves	16	75-80	550-600	54-55	0,2-0,4	- - -	0,7-0,9
Grass silage	25-50	70-95	550-620	54-55	3,5-6,9	6,9-19,8	0,4-0,8
Food-processing by-products							
Beer sediments	20-25	70-80	580-750	59-60	4-5	- - -	1,5
Grain slops	6-8	83-88	430-700	58-65	6-10		3,6-6
Potatoe slops	6-7	85-95	400-700	58-65	5-13		0,9
Fruit slops	2-3	95	300-650	58-65	- - -		0,73
Crushed material (fresh)	13	90	650-750	52-65	0,5-1	0,04	0,1-0,2

Fruit juice (water)	3,7	70-75	1500-2000	50-60	4-5	0,8-1	2,5-3
Water from the processing (?)	1,6	65-90	3000-4500	50-60	7-8	0,6-0,8	2-2,5
Compacted slices	22-26	95	250-350	70-75	- - -		- - -
Molasses	80-90	85-90	360-490	70-75	1,5		0,3
Apple mouldings	25-45	85-90	660-680	65-70	1,1		0,3
Fruit mouldings	25-45	90-95	590-660	65-70	1-1,2		0,5-0,6
Grape mouldings	40-50	80-90	640-690	65-70	1,5-3		0,8-1,7
Biological municipal waste							
Compostainers	40-75	50-70	150-600	58-65	0,5-2,7	0,05-0,2	0,2-0,8
Left-over food	9-37	80-98	200-500	45-61	0,6-5	0,01-1,1	0,3-1,5
Left-overs from sale	5-20	80-90	400-600	60-65	3-5	- - -	0,8
Fat	2-70	75-93	700	60-72	0,1-3,6	0,02-1,5	0,1-0,6
Floatation sludge	5-24	80-95	900-1200	60-72	3,2-8,9	0,01-0,06	0,9-3
Mowed grass	12	83-92	550-680	55-65	2-3		1,5-2
Waste from abattoir							
Contents of guts	12-15	75-86	250-450	60-70	2,5-2,7	- - -	1,05
Contents of stomacks	11-19	80-90	200-400	58-62	1,3-2,2	0,4-0,7	1,1-1,6
Total							

Based on the data stated above a theoretical potential for the particular EU member countries was calculated. The results of the calculation are summarized in the following chart:

Table 4: Theoretical potential

	Ejecta of livestock	Biomass growed purposely	Biodegradable waste from industry	Municipal waste	TOTAL
	(PJ/year)	(PJ/year)	(PJ/year)	(PJ/year)	(PJ/year)
Belgium	24	7	0	4	35
Bulgaria	7	27	0	3	37
Czech Republic	12	19	1	3	34
Denmark	30	14	2	4	51
Germany	120	89	14	41	264
Estonia	2	4	0	1	7
Ireland	35	23	0	3	61
Greece	10	17	0	4	32
Spain	86	133	5	23	247
France (1)	129	155	20	31	335
Italy	57	77	13	29	175
Cyprus	1	1	0	1	3
Latvia	3	9	0	1	13
Lithuania	7	15	0	1	23
Luxembourg	1	1	0	0	2
Hungary	11	31	1	4	47
Malta	0	0	0	0	1
Netherlands	44	10	7	9	69
Austria	17	17	7	5	45
Poland	65	84	4	9	161
Portugal	13	20	3	4	40
Romania	35	75	1	7	118
Slovenia	4	3	0	1	7
Slovakia	5	10	0	1	17
Finland	8	12	6	2	28
Sweden	11	17	11	4	43
United Kingdom	73	88	16	31	209
EU-27 (1)	811	957	111	225	2 105

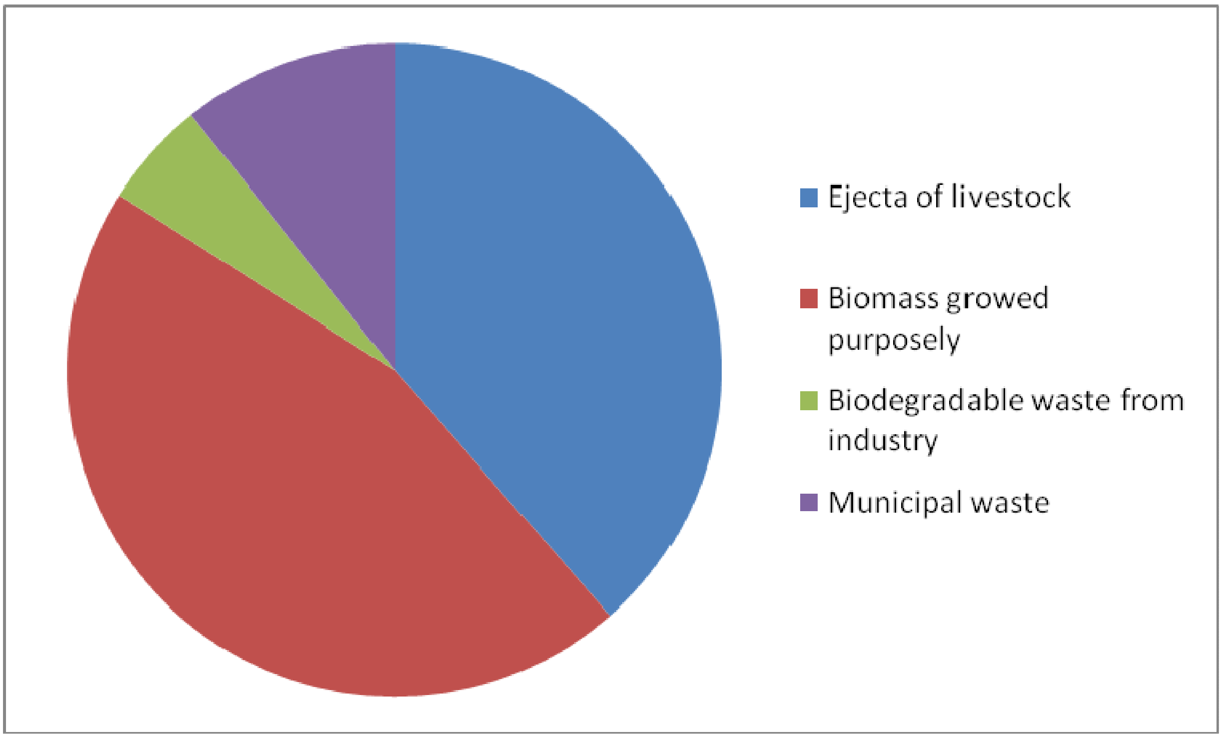

Figure 2: Proportion of the particular input materials in the total potential (EU27)

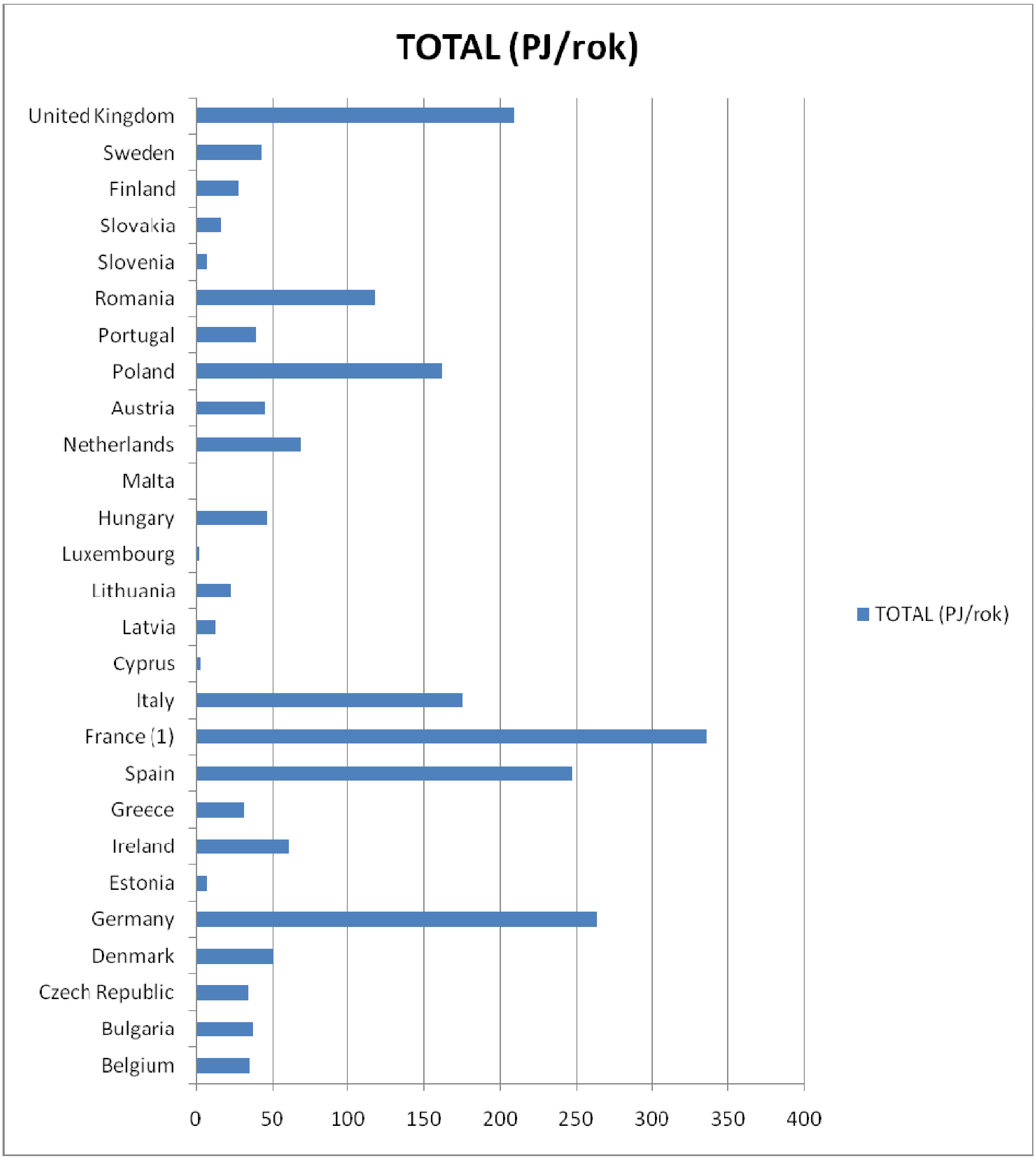

Figure 3: Total potential of the power generation from biogas for the invidual EU countries

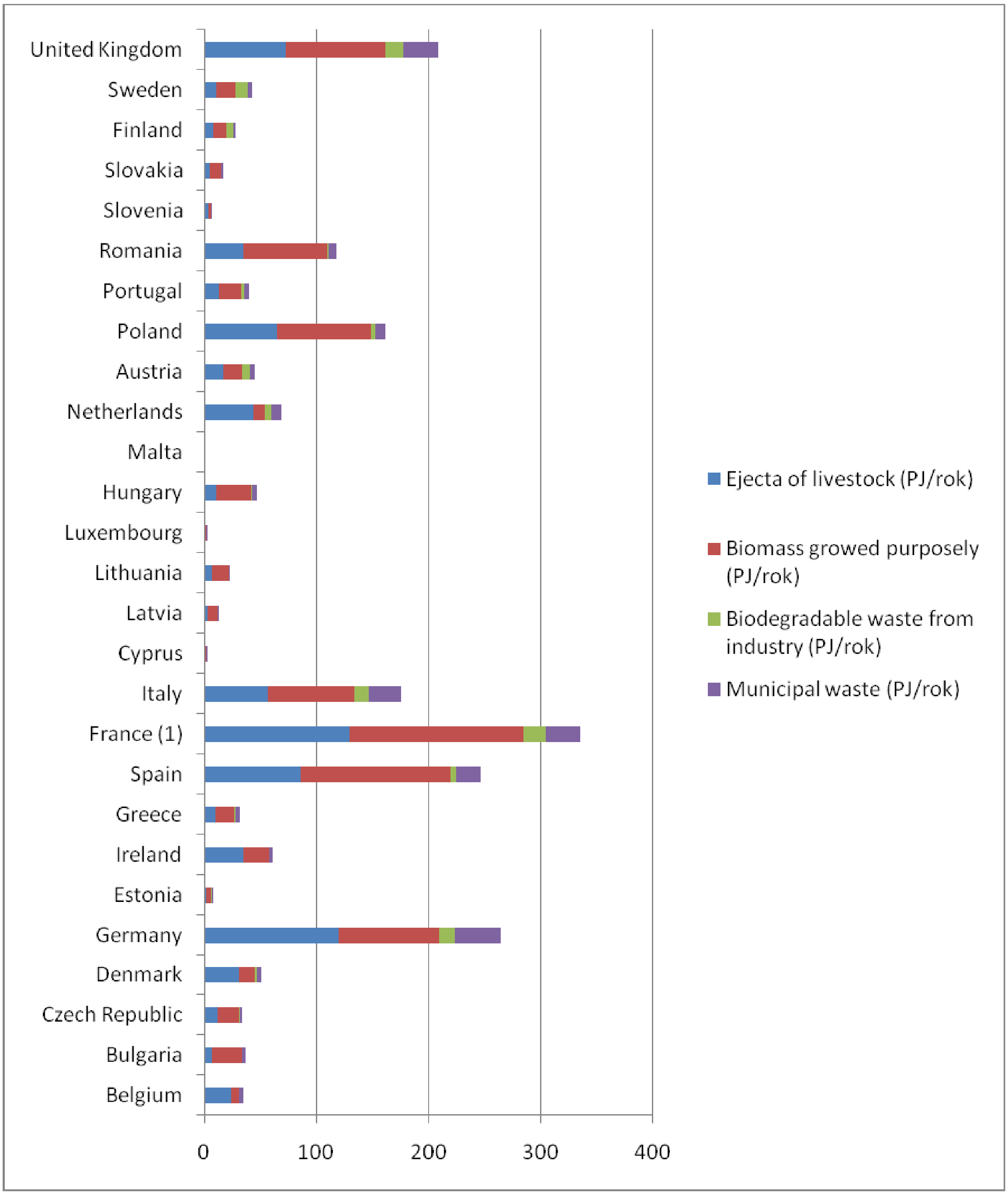

Figure 4: **Potential of the power generation from biogas showing the particular resources for the individual EU countries**

Technological (available) potential

It is a potential that is limited by technological, administrative, legislative environmental and other limitations. These limitations are known and we can take them into account quite easily.

Factors determining the utilization of the potential

- Sufficiency of input materials is the basic supposition for preparation of the project
- The legislative environment of every member state forms the basic frame
- The public meaning is one of the determining factors and also one of the main obstructions to the realization
- Guarantee of the production sales is an important factor for securing sustainability

Availabilty of subsidies and grants

The subsidies can be single investement grants or long-term performance-oriented subsidies.

Subventions for the general enforcement of the new technology are very helpful. But basically subventions oriented on specific goal should be used.

For the biogas technology the performance-oriented subvention proofed to work as the best way of support (depending on the volume of power and heat produced per year).

On one hand the management people are by the performance-oriented subvention motivated to generate as much and as cheap power as possible.

Economically available potential

Economically available potential is part of the technological potential which can under current circumstances be realized, that means the part which is suitable for an economically effective utilization.

The economical conditions are currently very different in the individual EU countries. The main differences lie in the following conditions:

The return for the production sales

The production is the power generated from renewable sources. The way of the market utilization is very different in different countries. Deciding is the degree of support for the produced power in the form of heat and electricity, resp. setting the prices of energy in the form of gas.

An important element influencing the hight of the sales return is the price of the input material. This price is negative in the case of purposely growed agricultural production (that means it belongs to costs), but it is positive in the case of utilizing the waste (yield). The returns for the waste at the input can in many cases be higher than the return for the power sold.

Cost of investments

The cost of investments is the deciding factor for a long-term efficiency of a biogas plant. On one hand it is important for which price which components will be bought, on the other hand also what size and performance these components have.

The hight of investment is directly connected with the type and quality of the entering components. The enter part of the biogas plant processing only agricultural inputs is much less investment demanding than an enter part processing waste.

Other investment is connected with the requirements of the form and production quality. The basic differences in the investment demands are caused by the following:

- Digestate quality requirements (liquid, partly dried, dried…)
- Energy output quality requirements
    - gas (pressure, purity, connection…)
    - heat (messuring, form, temperature, guarancy of the supply….)
    - electricity (quality, permanence and guarancy of the supply, network connection…)
- Way of covering the cost of investments
- Own resources and bank loan – optimalization of the investment
- Availability of subsidies and grants - the subsidies can be single investements grants or long-term performance-oriented subsidies Subventions for the general enforcement of the new technology are very helpful. But basically subventions oriented on specific goal should be used. For the biogas technology the performance-oriented subvention proofed to work as the best way of support (depending on the volume of power and heat produced per year). By the performance-oriented subvention the responsible people are motivated to generate as much and as cheap power as possible, whereas the investment support sometimes leads to building of technologies which are not optimal. The performance oriented support is a good means to regulate the cost of investments, which at the and contributs to the efficiency of the biogas plant.

The following tools are used for stating the economically available potential

4. Economic tools for evaluating the projects

Each project concerning the use of renewable resources has its own environmental as well as economic implications. The investor, be it a company, an individual, a community or some other subject, is always somehow interested in the economical results of the project.

An important factor for the decision of the investor is the calculation of the economic impact of the evaluated projects on his economics while respecting fair rules of an economic decision and also the economic situation in which the investor at the time of preparating the investment currently is. The results of the economic evaluation must be known also to the institutions which provide some part of the needed means in the form of loans or a financial support or subvention.

It is obvious, that there will appear a discrepance between results of the evaluation in which its criteria maximize the economic effect and the evaluation where the criteria minimize the emissions, usage and energy wasting. This discrepance is created not because some of the criteria would be basically unsuitable, but because they represent different points of view at the same issue. It is for example possible to attain very low energy loss in the gas distribution but for the price of extremely high pipe insulation costs which could be more efficiently used for other equipment.

Accordance between the economical, environmental, energetical and other criteria could happen only in the case when the prices of all forms of energy would not include only the costs for acquiring the energy, its modification, transfer and distribution, but also economically expressed impacts on other subjects (environmental harms, people´s health harms etc.) – see for example /6/. A requirement of such energy price category is theoretically elaborated, but it wasn´t successfully filled with figures yet.

Economics as a strong influencing element of the social values strongly conditions the activity of production factors and becomes even a deciding element.

Good results of the economical evaluation indicate the feasibility of the project which then has a high chance to succeed on the market.

In this situation the production of biogas has very positive implications in the terms of micro- and macro-economy. It doesn´t recede from the economical reality and for this reason it needs to improve and evolve constantly to be able to provide a general benefit for the society and for the actual biogas production.

Basic principles for the economical evaluation of the projects

If we are to evaluate the lucrativeness of a prospectus in energy sector, unlike in some other sectors we can´t avoid the long-term nature of this task. When evaluating the economical efficiency of energy projects it is necessary to follow some generally respected principles to which belong mainly the following:

- Calculation based on cash flow, caused by the evaluated investment, project,
- Use of the right criteria for the economical efficiency NPV or IRR,
- Including all relevant parts incl. return of the actual funds (rebate, the value of the money in time) into the evaluation,
- Strict use of marginal quantities invoked by the decision to realize the evaluated project (the evaluation must include the future values of all changes of cash flow caused by the project),
- Calculation in usual (nominal) prices while respecting the price development of the particular items of gains and expenses,
- Choice of right period for comparing based on the period of economical durability of the investment, that means the time in which the cash flow for the particular project will be observed,
- Respecting the possible effects of the project after the evaluation period is finished (liquidation, residual value),
- Use of the adequate criteria for the evaluation (project as a whole, the aspect of the investor),
- When calculataing the cash flow from the viewpoint of the investor:
- Respecting the effects of sponsoring (own funds, loan, obligations, resp. investments or other support),
- Respecting the tax connections (tax depreciations, interest, tax loss, etc.).

To the task usually doesn´t only belong to express in numbers the value of the economical efficiency criteria (NPV, IRR), but also (or mainly) to find the so called minimum cost of the production which should be regarded as a minimum value which will make the project for us as an investor still economically interesting. The minimum prices (of the heat supplied, power generated, electricity generated, biomass grown etc.) at the same time anables the investor to consider practically the possibility of selling the production, that means whether it will be able to compete by this price.

Aspects of the economical evaluation of the energy projects

The approach in economical evaluating of investements can be divided according to the kind of the subject who prepars the investment, evaluates, resp. provides means for its realization and bears the economical impact of the realization. In principle we can define following, more or less different viewpoints:

System viewpoint (sometimes also described as the project viewpoint) which respects the overall demands and effects of the suggested project in its entirety, regardless of how the total economic effect wil be devided and what the origin of the capital invested is (own investor´s funds, loan capital, public finance, etc.),

total capital viewpoint which represents the common viewpoint of the own investor´s (investors´) capital and the foreign, loan capital, where only bussines subjects are included into this evaluation and the gain tax and the interest gains are substracted as an inevitable expense element,

Investor´s viewpoint which restricts the evaluation only to the viewpoint of the own capital invested by the investor. This investing subject can be:

- bussines subject; the efficiency of the project must be able to compete with other bussines activities (by this the expected return of the invested capital is defined),

- a non-bussines subject like for example a household, but also a community, a state, a budget or some other institution, where the financial means for the project financing are to a certain degree of a public kind and their investment and expected economical effects are compared with an alternative investment within these budgets.

The project viewpoint can to a certain degree be regarded as a systemic approach to the evaluation, but only in its economical part. But as a systemic approach to the evaluation is usually regarded an approach that includes more subjects concerned into the evaluation and takes into account the financially unexpressable effects of the projects. This can even lead to the necessity of using the methods of more-criteria evaluation of the variants. The methods of more-criterial evaluation enable us to include also other than direct economical effects of the project (environmental, social,…), but their use requires an accurate formulation of the problem, used criteria and evaluation methods and a number of other premises.

Let´s take a look at possibilities and limitations of the approach that evaluates the project as a whole. The advantage is that we get an idea about the effectiveness of the project as a whole, because we will be comparing the project demands from the viewpoint of the total capital invested with all the (economical) project effects, regardless of their dividing and later employment. So for example even a paid tax means a return from the project realization, although it goes to the state or other budget.

The disadvantage is that for the investor (the net gain, resp. free cash flow) is only a part of the total effect and this part might not be interesting for a specific investor. That means that it can happen that the project in its entirety is economically interesting, but not for the investor, so at the end it might not get implemented.

It´s obvious that the evaluation from the viewpouint of the project can serve very well in the case that we need to evaluate different projects and solutions right from the aspect of their total demands and effects. But if the project is at the same time not interesting for an investor, it is appropriate to look for some tools and ways of subsidization which will make the project an interesting bussines opportunity. The mentioned procedure is suitable also in the cases when the project effects and profits are not financially expressable, but are corresponding with the social interests.

Procedure of the economical evaluation

The calculation of rebatted future cash flow within the period of the economical persistence of the project seems to be optimal, while taking into account the expected evolvement of the particular expense and gain items.

$$CF_t = V_t - N_{pt} - N_{út} - D_t - ZS_t - N_{ivlt} - S_{plt}$$

Pure cash flow of the investor´s funds CFt, is determined by the relation

where:

V are the earnings (sales, savings) coming from the implementation of the evaluated variant,

N_p operational costs of the facility (material, fuel, energy, water, repairs and maintanance, wages and other costs including the emission fees),

$$D = d_z (V - N_p - N_{od} \pm P)$$

$N_{ú}$ interests paid from the loans,

D profit tax of the investor calculated by the relation

N_{od} depreciation of the given equipment,

P extra expenses that can be added (+) resp. deducted (-) when calculating the profit tax base (for example fees and penalties which are not included in the tax base),

ZS single-shot expenses for purchasing the necessary inventory (for example spare parts), paid usually in the time of the building-up,

S_{pl} loan amortization at the point of acquitance,

N_{ivl} investment funds paid from own investror´s recources

d_z profit tax rate of the investor,

t individual years oft he evaluated period.

If we calculate the effectiveness from the point of view oft he real investor, we should know the possible ways of financing and obviously we also include the reals effects of the taxation into the calculation. At the same time it can happen that the evaluation period whereof economical effects we calculate, can strongly vary from the period of persistence of the depreciation of particular parts of property. It will usually also differentiate from the tax amortization period. Then it is good to think about possible cycles of renewal of those parts of the equipment that have a shorter period of economical durability than the evaluated period.

An objectively correct evaluation criterion is based on maximization the future cash flow. Taking into account the value of money in time we have to convert it to an addible value which can be best done by calculating the so called net present value (NPV) and rebatting it at the correctly chosen moment (usually at the beginning of the first year of activity).

$$NPV_{T_i} = \sum_{T=1}^{T_i} CF_T \cdot (1+r)^{-T}$$

<u>This criterion fullfills all required conditions, as:</u>

It consequently uses the changes of cash flow caused by the evaluated project (relevant, marginal quantities),

the criterion includes the future expenses and gains and thereby it automatically leaves out the already ”lost” financial means,

it includes all relevant items uncl. the return of own capital (rebate),

it is able to take into account the structure of financing and taxation according to the specific investor´s situation.

Mathematicaly we can come to three basic results:

NPV > 0	the project can be recommended for implementation, the returns from the project are higher than the capital invested
NPV = 0	the project is on the borderline of profitability
NPV < 0	the project is not suitable for implementation

If we have more options to choose from, we choose according to this criterion the option with the highest NPV rate.

$$NPV \rightarrow \max$$

In the case that there is no possibility of so called zero option (the option to not realize the project) and all the alternates of technological solutions have only negative NPV rates, than we choose the one which is the closest to zero, that means the least loss.

The NPV criterion enables us to determine also the **so called minimum production price** (that means the price of the production in the first year of the evaluated period) from the condition NPV=0. In this case the investor makes the return from the capital invested in the hight of the rebate.

Other criterion used for evaluating the investments is the Internal Rate of Return - IRR, which is such a rate of return which used for rabatting gives exactly zero rate of the rabatted cash flow for the period of persistence. Its certain advantage is that it can be interpreted in comparing to the rate of return, so it is often used for comparing of projects of different size. Its disadvantage is its relative nature, so it is not suitable for comparation of investments which are very different in their volume. Another disadvantage of this criterion is that it is not always mathematically definite, resp. the IRR might not exist at all. The following relation applies:

$$NPV_{T_i} = \sum_{T=1}^{T_i} CF_T \cdot (1 + IRR)^{-T} \rightarrow 0$$

$$IRR \rightarrow \max$$

To other commonly used criterions for the investment evaluation belongs the payback period. The deciding point is here the as quick as possible payback of the investment from the future gains. But that doesn´t mean at all, that throughout the whole period of persistence the effect will be maximal. The mistake of both the modifications of this payback period criterion is that it leaves out all the expenses and earnings after the payback period, which causes an unwanted elimination of long-term projects. These can be used only as orientation and comparation values for simple projects having similar technological solutions with the same time of durability and the same way of financing.

5. Estimation of the potential for increasing the use of biogas when using the best practices

There is calculated potential amount of energy supplied to final consumers, and the saved air pollutant emissions for the current situation when using the best practises in the following tables and graphs. The input data come from the previous calculations.

The comparison is done in energy and environmental point-of-view. The economic comparison cannot be so generally done, because the input conditions (price of electricity, price of heat, cold price, level of support…) are so different in each country that the results should not be any explanatory power. It can be conculded that all economic parameters will be about twice better when using the best practices (see D02). For accurate determination of the economic comparison, the calculation tool, which is in the annex, was created.

The calculation is done for the total amount of energy in the form of heat, electricity and cold.

Table 5: The potential of supplied energy in the EU countries for as a bp

	Total potential	Output of energy	Output of energy
		AS*	BP*
	[PJ/year]	[PJ/year]	[PJ/year]
Belgium	35	12	29
Bulgaria	37	13	31
Czech Republic	34	12	29
Denmark	51	17	42
Germany	264	91	220
Estonia	7	2	6
Ireland	61	21	51
Greece	32	11	27
Spain	247	85	206
France (1)	335	116	280
Italy	175	60	146
Cyprus	3	1	2
Latvia	13	5	11
Lithuania	23	8	19
Luxembourg	2	1	2
Hungary	47	16	39
Malta	1	0	0
Netherlands	69	24	58
Austria	45	16	38
Poland	161	56	135
Portugal	40	14	33
Romania	118	41	99
Slovenia	7	2	6
Slovakia	17	6	14
Finland	28	10	24
Sweden	43	15	36
United Kingdom	209	72	174
EU-27 (1)	2 105	726	1757

* actual state

* best practices

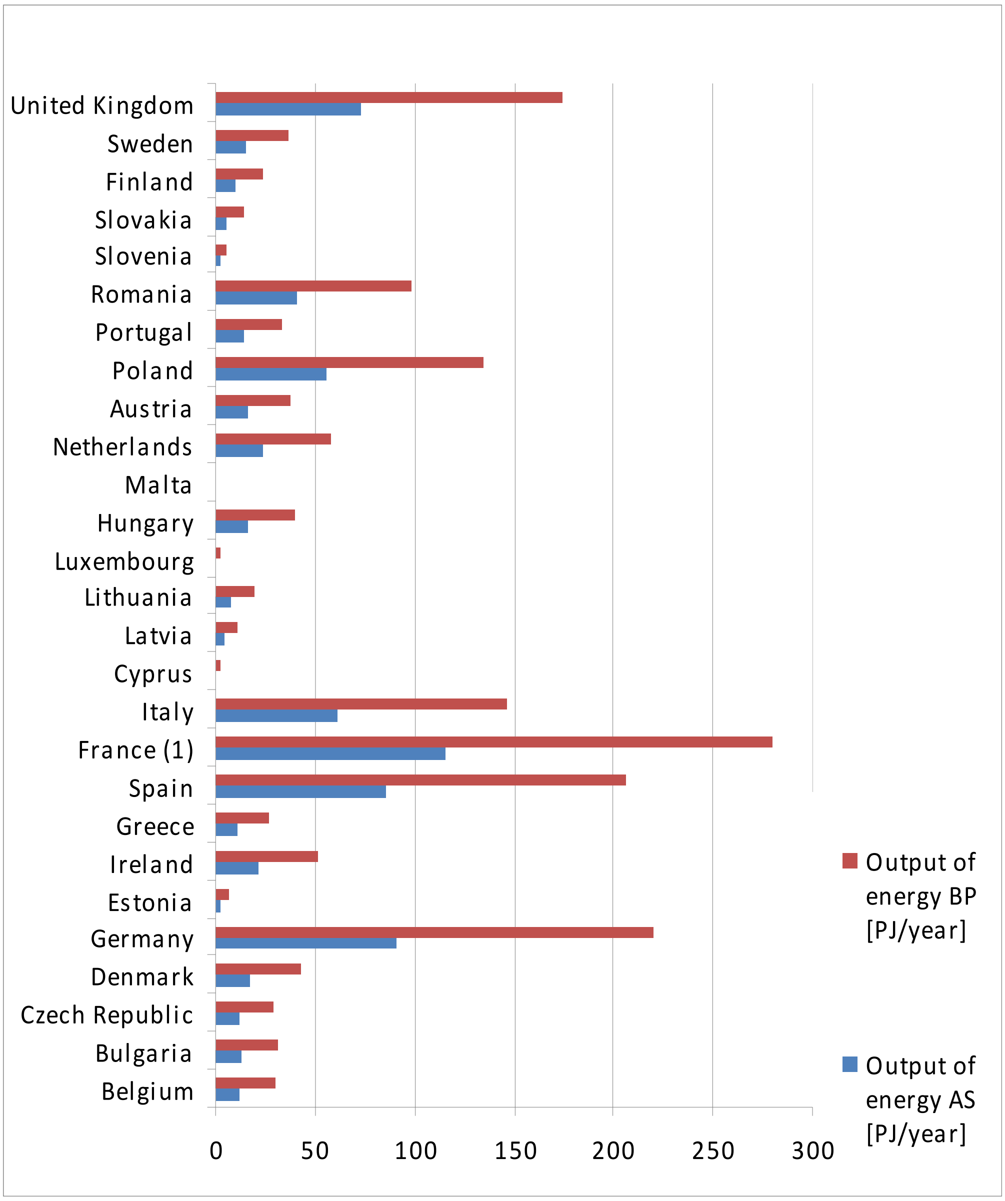

Figure 5: Graph – the potential of supplied energy in the EU countries for as a bp

The calculation of emissions saved when using the full potential is made for the basic air pollutants.

Table 6: Tab – the saved air pollutant emissions – actual state

	Solids	SO2	NOx	CO	CxHy	CO2	Amount of emissions
	AS						
	[kT]	[kT]	[kT]	[kT]	[kT]	[kT]	[kT]
Belgium	4	18	16	4	0	11452	**11493**
Bulgaria	4	19	16	4	0	12070	**12114**
Czech Republic	4	18	15	4	0	11176	**11216**
Denmark	5	26	22	6	0	16460	**16520**
Germany	27	137	116	29	0	85798	**86109**
Estonia	1	4	3	1	0	2297	**2305**
Ireland	6	32	27	7	0	19912	**19984**
Greece	3	17	14	4	0	10404	**10442**
Spain	26	128	109	27	0	80202	**80492**
France (1)	35	175	148	37	0	109011	**109406**
Italy	18	91	77	19	0	56954	**57160**
Cyprus	0	1	1	0	0	853	**856**
Latvia	1	7	6	1	0	4319	**4334**
Lithuania	2	12	10	3	0	7452	**7479**
Luxembourg	0	1	1	0	0	702	**704**
Hungary	5	24	21	5	0	15193	**15248**
Malta	0	0	0	0	0	177	**177**
Netherlands	7	36	31	8	0	22502	**22583**
Austria	5	23	20	5	0	14639	**14692**
Poland	17	84	71	18	0	52438	**52628**

Portugal	4	21	17	4	0	12886	**12932**
Romania	12	61	52	13	0	38393	**38532**
Slovenia	1	4	3	1	0	2251	**2259**
Slovakia	2	9	7	2	0	5426	**5446**
Finland	3	15	13	3	0	9227	**9261**
Sweden	4	22	19	5	0	13924	**13974**
United Kingdom	22	109	92	23	0	67901	**68147**
EU-27 (1)	219	1095	928	234	1	684017	**686494**

Table 7: Tab – the saved air pollutant emissions – best practices

	Solids	SO2	NOx	CO	CxHy	CO2	Amount of emissions
	BP						
	[kT]	[kT]	[kT]	[kT]	[kT]	[kT]	[kT]
Belgium	35	64	20	132	26	15278	**15554**
Bulgaria	37	67	21	139	27	16102	**16393**
Czech Republic	34	62	19	129	25	14909	**15179**
Denmark	50	92	28	190	37	21959	**22356**
Germany	261	479	147	991	194	114459	**116530**
Estonia	7	13	4	27	5	3064	**3119**
Ireland	61	111	34	230	45	26563	**27044**
Greece	32	58	18	120	23	13880	**14131**
Spain	244	448	138	926	181	106993	**108929**
France (1)	331	609	187	1259	246	145426	**148058**
Italy	173	318	98	658	129	75980	**77355**
Cyprus	3	5	1	10	2	1138	**1158**
Latvia	13	24	7	50	10	5761	**5866**
Lithuania	23	42	13	86	17	9942	**10122**
Luxembourg	2	4	1	8	2	936	**953**
Hungary	46	85	26	175	34	20268	**20635**
Malta	1	1	0	2	0	235	**240**
Netherlands	68	126	39	260	51	30018	**30562**
Austria	44	82	25	169	33	19530	**19883**
Poland	159	293	90	606	118	69955	**71221**

Portugal	39	72	22	149	29	17190	**17501**
Romania	117	214	66	443	87	51219	**52146**
Slovenia	7	13	4	26	5	3003	**3057**
Slovakia	16	30	9	63	12	7239	**7370**
Finland	28	52	16	107	21	12310	**12533**
Sweden	42	78	24	161	31	18575	**18911**
United Kingdom	206	379	116	784	153	90583	**92222**
EU-27 (1)	2079	3819	1174	7899	1543	912514	**929027**

Table 8: **Tab – The comparison of the saved air pollutant emissions – actual state and the best practice state**

	Total potential	CO_2	Amount of emissions	CO_2	Amount of emissions
		AS		BP	
	[PJ/year]	[kT]	[kT]	[kT]	[kT]
Belgium	35	11452	**11493**	15278	**15554**
Bulgaria	37	12070	**12114**	16102	**16393**
Czech Republic	34	11176	**11216**	14909	**15179**
Denmark	51	16460	**16520**	21959	**22356**
Germany	264	85798	**86109**	114459	**116530**
Estonia	7	2297	**2305**	3064	**3119**
Ireland	61	19912	**19984**	26563	**27044**
Greece	32	10404	**10442**	13880	**14131**
Spain	247	80202	**80492**	106993	**108929**
France (1)	335	109011	**109406**	145426	**148058**
Italy	175	56954	**57160**	75980	**77355**
Cyprus	3	853	**856**	1138	**1158**
Latvia	13	4319	**4334**	5761	**5866**
Lithuania	23	7452	**7479**	9942	**10122**
Luxembourg	2	702	**704**	936	**953**
Hungary	47	15193	**15248**	20268	**20635**
Malta	1	177	**177**	235	**240**
Netherlands	69	22502	**22583**	30018	**30562**
Austria	45	14639	**14692**	19530	**19883**

Poland	161	52438	**52628**	69955	**71221**
Portugal	40	12886	**12932**	17190	**17501**
Romania	118	38393	**38532**	51219	**52146**
Slovenia	7	2251	**2259**	3003	**3057**
Slovakia	17	5426	**5446**	7239	**7370**
Finland	28	9227	**9261**	12310	**12533**
Sweden	43	13924	**13974**	18575	**18911**
United Kingdom	209	67901	**68147**	90583	**92222**
EU-27 (1)	2 105	684017	**686494**	912514	**929027**

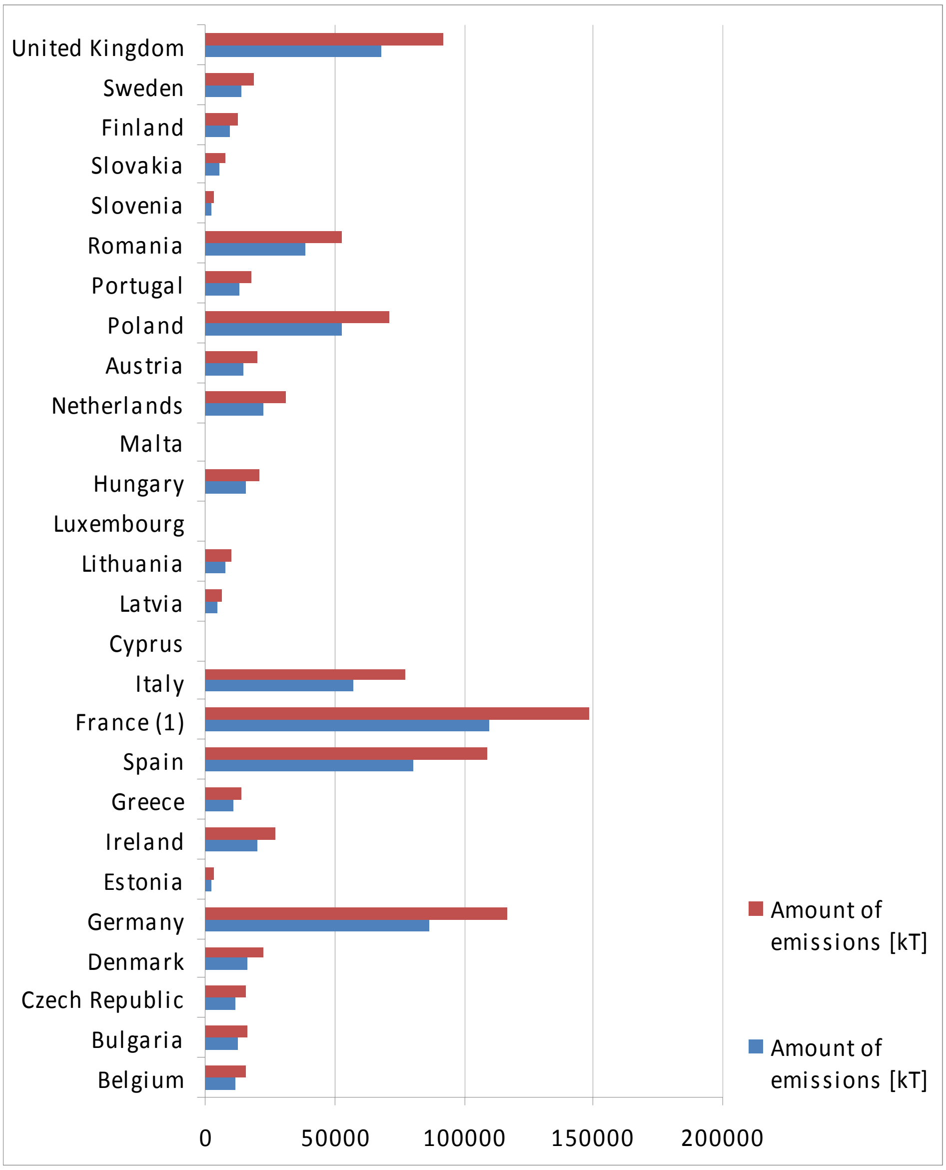

Figure 6: **Graph – The comparison of the saved air pollutant emissions – actual state and the best practice state**

Further, there is an example of the calculation the economic efficiency under the current conditions and when using the best practices. The calculation is done for a specific biogas station with the production of biogas 1848110 Nm3 per year. The calculation is done for economic conditions in the Czech Republic.

Example 1 - economic conditions when using the current practices

Investment costs		[thousands €]	2 700
	Technology	[thousands €]	1 350
	Building	[thousands €]	1 350
Economic parameters	Discount	[%]	8,00%
	Income tax	[%]	19,00%
	Tax immunity	[years]	5
	Price of electricity	[€/MWh]	0,1
	Price of heat	[€/MWh]	0
	Price of biogas	[€/Nm^3]	0
	Period of evaluation	[years]	20
	Yearly increase	[%]	2,00%
Costs	Variable operational costs	[thousands €]	79
	Fixed operational costs	[thousands €]	0
	Other operational costs	[thousands €]	0
	Input raw materials costs	[thousands €]	0
	Yearly increase	[%]	2,00%
Self consumption	Electricity	[%]	6,00%
	Heat	[%]	20,00%
Energy balance	Amount of biogas input	[Nm^3]	1848110

	Methane volume	[%]	60%
	Yearly production of methane	[Nm³]	1 108 866
	Fuel efficiency (heating power)	[kWh/m³]	10
	Gross energy	[MWh/year]	11 089
	Electricity supply	[MWh/year]	3 669
	Heat supply	[MWh/year]	4 906
	Biogas for sale	[Nm³/year]	0
Cogeneration unit	Total	[%]	90,5%
	Electrical efficiency	[%]	35,2%
	Heat efficiency	[%]	55,3%

Investment costs	[thousands €]	**2 700**
Operational costs	[thousands €]	**79**
Revenues - electricity	[thousands €]	**367**
Revenues - heat	[thousands €]	**0**
NPV	[thousands €]	**273**
IRR	[%]	**9,40%**
Payback period	[years]	**9**
Discounted payback period	[years]	**16**

Example 2 - economic conditions when using the best practices

Investment costs		[thousands €]	2 700
	Technology	[thousands €]	1 350
	Building	[thousands €]	1 350
Economic parameters	Discount	[%]	8,00%
	Income tax	[%]	19,00%
	Tax immunity	[years]	5
	Price of electricity	[€/MWh]	0,1
	Price of heat	[€/MWh]	0,07
	Price of biogas	[€/Nm^3]	0
	Period of evaluation	[years]	20
	Yearly increase	[%]	2,00%
Costs	Variable operational costs	[thousands €]	79
	Fixed operational costs	[thousands €]	0
	Other operational costs	[thousands €]	0
	Input raw materials costs	[thousands €]	0
	Yearly increase	[%]	2,00%
Self consumption	Electricity	[%]	6,00%
	Heat	[%]	20,00%
Energy balance	Amount of biogas input	[Nm^3]	1848110

	Methane volume	[%]	60%
	Yearly production of methane	[Nm^3]	1 108 866
	Fuel efficiency (heating power)	[kWh/m^3]	10
	Gross energy	[MWh/year]	11 089
	Electricity supply	[MWh/year]	3 669
	Heat supply	[MWh/year]	4 906
	Biogas for sale	[Nm^3/year]	0
Cogeneration unit	Total	[%]	90,5%
	Electrical efficiency	[%]	35,2%
	Heat efficiency	[%]	55,3%

Investment costs	[thousands €]	**2 700**
Operational costs	[thousands €]	**79**
Revenues - electricity	[thousands €]	**367**
Revenues - heat	[thousands €]	**343**
NPV	[thousands €]	**3 448**
IRR	[%]	**23,56%**
Payback period	[years]	**4**
Discounted payback period	[years]	**5**

6. Conclusion

Last we can state that the energy potential of anaerobic digestion is currently used only partially in the frame of the EU-27. This use is strongly varies in different member countries. The fundamental factor determining the degree of utilization of the theoretical potential is the legislative environment of each particular country. Above all the guarancy of sales and production price have the dominant influence.

By preparation of the specific project the most important thing is to maximize the use of the starting potential, this means a maximum utilization of of the entering energy potential. This utilization depends on the optimizing of the technological chain, which consists of preparation and gathering of the input material, the biogas production technology, gas modification technology and energetical utilization of the produces gas.

For the actual project implementation the economical awareness is an important parameter. A perfectly optimalized setup of technology with precisely defined output is a supposition for the functioning of the project. This procedure is the base of a realistic sustainability of the project for the whole period of its technological and moral persistence.

In the broader context it is necessary to respect the economically unmessurable factors, to which belongs mainly the reducing of the environmental impact. The aim of each member country is to limit the impacts of energy production and consumption on the environment.

Many states have already included these factors into their legislative and there also exists an economic appreciation connected with these aims. The example could be differently setted valorized redemption prices for the electricity form renewable recourses (form of bonuses), or on the contrary purchasing of permits (form of sanctions).

7. Literature

[1] Využití bioplynu v zemědělství, 2008 [Using the biogas in agriculture]

[2] http://www.dagger.cz

[3] http://www.keajc.cz

[4] http://www.enviport.cz/

[5] http://www.agrifair.cz/

[6] http://www.cogen.cz/

[7] http://www.eurostat.eu/

[8] http://kogenerace.tedom.cz/

[9] Alternativní využití bioplynu, Ing. Michal Žídek, 2003 [Alternative use sof biogas]

[10] Dohányos M., Zábranská J., Jeníček P., (1996) Anaerobní technologie v ochraně životního prostředí, MŽP [Anaerobic technologies in environment protection]

[11] Váňa J., Slejška A., Bioplyn z rostlinné biomasy (1998) [Biogas from vegetable biomass]

[12] Schulz H., Eder B., (2004) Bioplyn v praxi [Biogas in practice]

[13] Straka F. Bioplyn (2003) [Biogas]

[14] Metodika analýzy potenciálu na konkrétním případě Semilska, Kamila Havlíčková, VÚKOZ Průhonice, oddělení fytoenergetiky [Methods of analyzing the potential on the example of the region of Semily]

[15] Hodnocení ekonomické efektivnosti projektů využívajících obnovitelné zdroje energie [Evaluation of the economic effectiveness of the projects using renewable energy recourses], Doc. Ing. Jaroslav Knápek, CSc, Doc. Ing. Jiří Vašíček, CSc, ČVUT FEL, katedra ekonomiky, manažerství a humanitních věd, Technická 2, 166 27 Praha 6