Project: BiG>East

(EIE/07/214)

WP 2.8
Biogas Potential in Greece
Summary Report

Deliverable 2.2

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Based on BIG>EAST partners Deliverables within WP2

February 2009

With the support of:

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1. Introduction

This report was compiled in the frame of the BIG>EAST project (EIE/07/214), which is supported by the European Commission within the Intelligent Energy for Europe programme.

The purpose of this report is to give an overview concerning the potential of biogas in Greece. The following pages illustrate and summaries the main findings of the WP2: Studies on Biogas Potential and more specifically the tasks Deliverables:

2.1 Assessment of existing biogas installations
2.2 Technical review of the utilization of waste material for biogas production
2.3 Estimation of feedstock availability
2.4 Assessment of agricultural structures
2.5 Biogas purification and assessment of the natural gas grid
2.6 Assessment of the utilization of biogas
2.7 Assessment of the impacts

Based on the reports compiled within WP2 by the BIG>EAST partners.

The report is one of a series of six reports dealing with the target countries of the BiG>East project: Bulgaria, Croatia, Greece, Latvia, Romania, and Slovenia. The target group of this report is mainly Politicians, Researchers, Decision makers and the general public.

2. Assessment of existing biogas installations

2.1 Biogas status in Greece

The term «biogas» hides a wide range not only in the ways in which it is valorised but also the technologies in which it is produced. Biogas can be produced using digesters or collected by the landfill sites. Currently (2007) fifteen biogas plants are in operation in Greece as it is shown in **Figure 1**[1]. The collection of the required data was done through a country wide field survey at biogas plants covered by CRES every year. The utilisation of biogas in most of these cases mainly covers heat demands of the plants. Nevertheless, the installed capacity of electricity generation from biogas was 37.4 MW and the gross electricity generation reached to 155.9 GWh[2]. The most energy was produced in the area of Athens due to the operation of the Municipal Wastewater Treatment Plant (MWTP) of Psytallia and the Sanitary landfill (SL) of Ano Liosia, which treat liquid and solid wastes respectively.

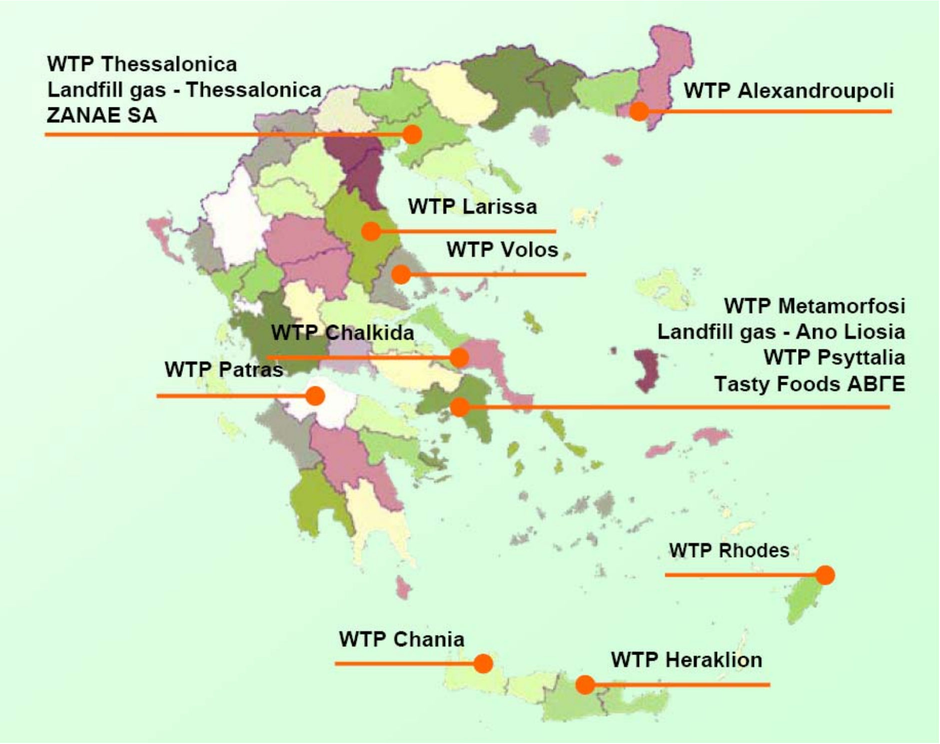

Figure 1: Biogas plants in Greece (in operation during 2007)

[1] CRES Energy Policy and Planning Division Database.
[2] Hellenic Transmission System Operator S.S (www.desmie.gr)

2.2 General view of the future

Biogas can be produced of nearly all kinds of organic materials. Nowadays in Europe, there are quite a few biogas process volumes at the current wastewater treatment plants, landfill gas installations, and industrial biowaste processing facilities. However, the largest volume of produced biogas will be, by 2020, originate form farm biogas and from large co-digestion biogas plants, integrated into the farming – and food – processing structures[3].

In Greece the picture is different as the produced biogas derives mainly from landfills, wastewater treatment plants and a couple of industrial applications. Although Greece has a promising potential of organic wastes and especially animal manure currently there is no farm scale biogas plant.

Nevertheless, in the framework of the calls for permits to generate electricity by Independent Power Producers (IPPs) by the Hellenic Regulation Authority for Energy (RAE, 2008) the most applications cover landfill plants and Municipal wastewater treatment plants. 37MW is already installed, while future projects for another 12MW from biogas plants have already received permits for power production from RAE (**Table 1**). If we take into account the announcements of the Athens Water Supply and Sewage Company (EYDAP SA) for the expansion of the biogas plant of Psytallia WWTP by 4.25MW and two new biogas projects namely a new CHP plant in the Metamorfosi cesspool waste treatment plant and a CHP plant in the new WWTP of West Attica–Thriasio (0.19MW), we can figure out that currently, there are some 5-6 biogas plants in Greece in different project phases. Furthermore, The Municipal Water Supply and Sewerage Company of Larissa (DEYAL) has requested a permit from RAE (October 2007) for a new biogas plant in the Sanitary Landfill of Makrychori (Parapotamos site).

Table 1: Biogas projects that have received production permit from RAE[4]

Location	Permit Number	Installed capacity	Fuel
Xanthi	ΑΔ.0310	9.5MW	MSW
Volos	ΑΔ.0805	1.72MW	Landfill gas
Larissa	ΑΔ. 0841	0.6MW	Sewage treatment biogas

[3] Nielsen J. and P. Oleskowicz-Popiel (2007): The future of Biogas in Europe: Visions and Targets until 2020, European Biogas Workshop The Future of Biogas in Europe – III, Esbjerg, Denmark.
[4] Regulatory Authority for Energy (RAE), www.rae.gr

3 Utilization of waste material for biogas production

Feedstock for Anaerobic Digestion plants can be derived mainly from three major categories (sources of wastes):

- Municipal waste (eg. landfill gas and wastewater treatment plants)
- Industrial waste (eg. dairy industries, food/beverage industries, slaughterhouses)
- Agricultural waste & energy crops (eg. cattle-pig-poultry manure, energy crops, agricultural residues).

The produced municipal solid wastes are disposed in landfills where organic matter is decomposed producing landfill gas. Thus, landfill gas is one of the most attractive systems for producing electricity and heat and is already a well known and established technology in Greece. Furthermore, biogas coming from the anaerobic digestion of wastewater sludge has been utilized for energy production.

Waste Management in Greece has been improved the last decade in terms of collection, recycling and facility development. The total quantity of Municipal Solid Wastes (MSW) in Greece increased rapidly over the last 10 years, from 3.2 million tones in 1995 to 4.447 million tones in 2000 and to 4.710 million tones in 2003. It is estimated that during 2006 the waste production come up to approx. 5 million tones. Landfilling of the municipal waste is still the predominant option (over 90% of the municipal waste generated).

Join Ministerial Decision 50910/2727/03 repeats the commitments of the Greek state to close down all illegal landfills by the end of 2008 and to reduce the biodegradable municipal waste to 35% by 2020. Intermediate targets are: 75% (2010) and 50% (2013). The targets will be achieved through the operation of recycling and composting facilities in almost all regions of the country as well as through the full operation of the separate collection systems for selected waste streams. It is worth mentioning that there is no specific source separation for the organic fraction of the municipal solid wastes and thus there is no facility processing such a stream.

Wastewater treatment in all parts of Europe has improved significantly since the 1980s. The actions in this area are based on the requirements of Directive 91/271/EC. Significant progress has been made in wastewater management and in 2006 the population covered by wastewater treatment plants (WWTP) was about 74% of the total population. According to the Greek Ministry of Environment WWTP will serve almost 90% of the Greek population by 2008 and must be constructed in the near future 151 new WWTP allover Greece.

Biogas production from some kind of industrial wastes seems to be an attractive alternative for the Greek industrial sector too. In some cases like in food industries the influences contain high amounts of easy biodegradable organic compounds, so they can be used for biogas production and use the thermal or electrical energy produced. In this way anaerobic digestion can be considered more as an energy production method than as a treatment one.

In Greece, sheep, goats and lambs breeding represent the highest percentage of livestock and its breeding is mainly done by shepherds. The largest portion of Greek livestock farming is extensive where the produced manure is spread on the grazing land[5]. Taking into account that the livestock farming is extensive the potential users of biogas production are mainly livestock units and especially medium and large ones. It is worth mentioning that although Greece has a promising potential of organic wastes and especially animal manure currently there is no farm scale biogas plant. Furthermore, a CAD plant is a viable option and a promising solution for the future.

Generally in Greece, the Anaerobic Digestion technology is used mainly as a waste treatment method but not accompanied with biogas and energy production (at least not in a wide extent at the moment). The general approach is that the waste are disposed after some treatment (aerobic or anaerobic) than the adaptation of a well know and integrated technology (AD) for parallel biogas production and the substrate use as fertilizer too. Furthermore, the wastes disposal (eg. manure) creates so far only a few problems compared to what happen to the other EU Member States (eg. West Europe). Thus, the implementation of biogas schemes for reduction of water and soil pollution is not so imperative in Greece until now. With available waste streams and infrastructure in place the conditions for biogas plants in Greece is an option. Options for sitting of facilities are numerous as they can be centralised or distributed as required.

[5] Chatziathanassiou A., I. Boukis (2000). Constrains and Strategy for the Development of Anaerobic Digestion in Livestock Farming in Greece. !st World Conference on Biomass for Energy and Industry, Sevilla Spain 5-9 June 2000.

4 Feedstock availability and Agricultural structure

The next paragraphs summaries the findings of the Deliverables under Task 2.3 and 2.4 submitted by the Romanian BIG>EAST partner MANGUS.

4.1 Energy crops

Figure 2 presents the theoretical potential of energy crops witch can be used for biogas investments in Greece. Energy crops stands here for total biomass generated on agricultural lands. Most of the part of these potential is used for human food and animal breeding. The spatial distribution reflects the higher potential on nuts level 2 GR12 and the lower GR22.

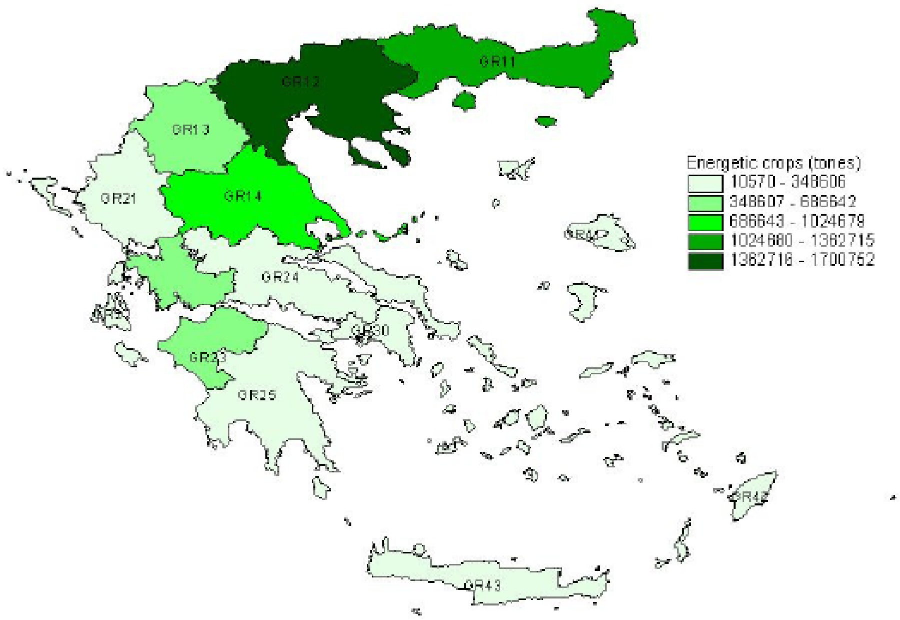

Figure 2: Potential feedstock based on energy crops

4.2 Agricultural wastes

The agriculture wastes may be used for energy production. Some of them could be also suitable for biogas production. The total agricultural wastes define the "theoretical availability". Not all this wastes are technically available. The residues from the annual (e.g. maize, cotton, cereals) and perennial (e.g. olives, vineyards) crops are the main categories of the agricultural residues in Greece. A portion of these residues can be used for energy purposes in general and some of them for Biogas production (theoretical availability) (see **Figure 3**). The residues production per Ha is based on the literature[6] and on the data registered at Eurostat. The manure was estimated taking into consideration the different type and weight of cattle and the manure specific production per animal and year, in liters (see **Figure 4**). The most promising animal manure for biogas exploitation is cattle, pigs and

[6] Energy Potential of Biomass – research in Greece region, Apostolakis – Kyritsis – Souter, 1987

poultry. The manure of the other animals, like sheeps and goats is spread to the grazing land so it can't be exploitable (extensive breeding).

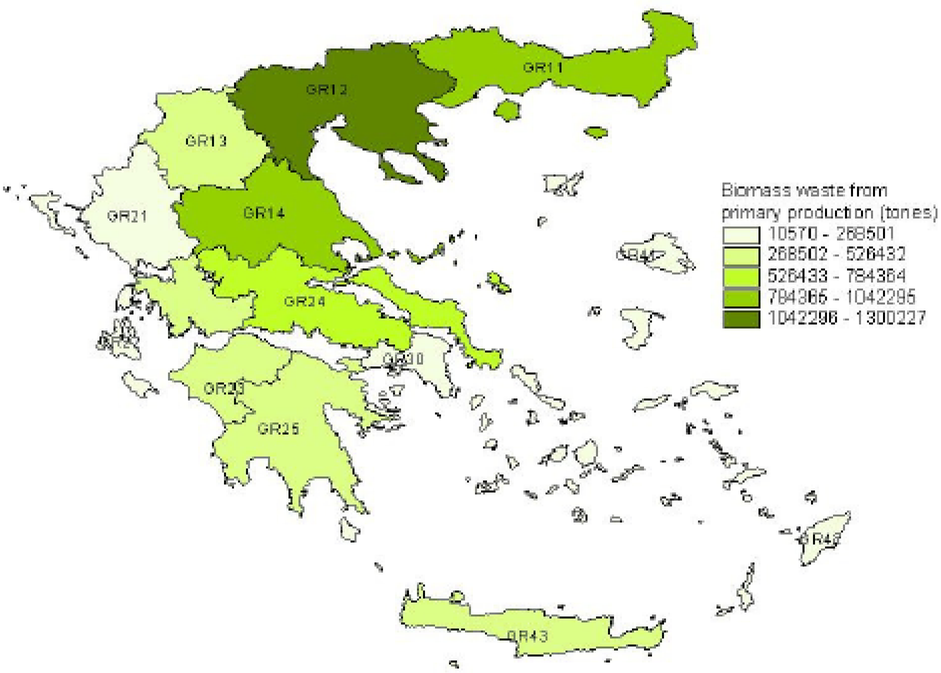

Figure 3: Agricultural waste from primary production

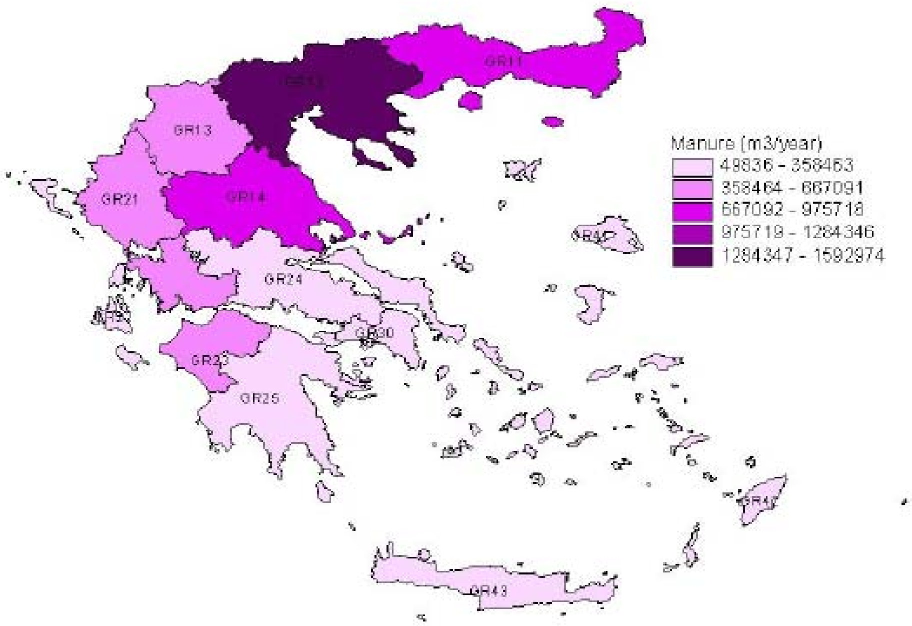

Figure 4: Agricultural waste from secondary production

4.3 Municipal waste and Sewage sludge

Based on data concerning the population and the tourism in Greece and the average production of domestic solid wastes (1.14kg/residence/day for the year 2001 based on JMD 50910/2727/23.12.2003) and tourists (roughly assumed the same waste production) and the proportion of food wastes (47% for the year 2001 based on JMD 50910/2727/23.12.2003) **Figure 5** and **6** presents the Organic Municipal Solid Waste and the Sewage Sludge waste respectively.

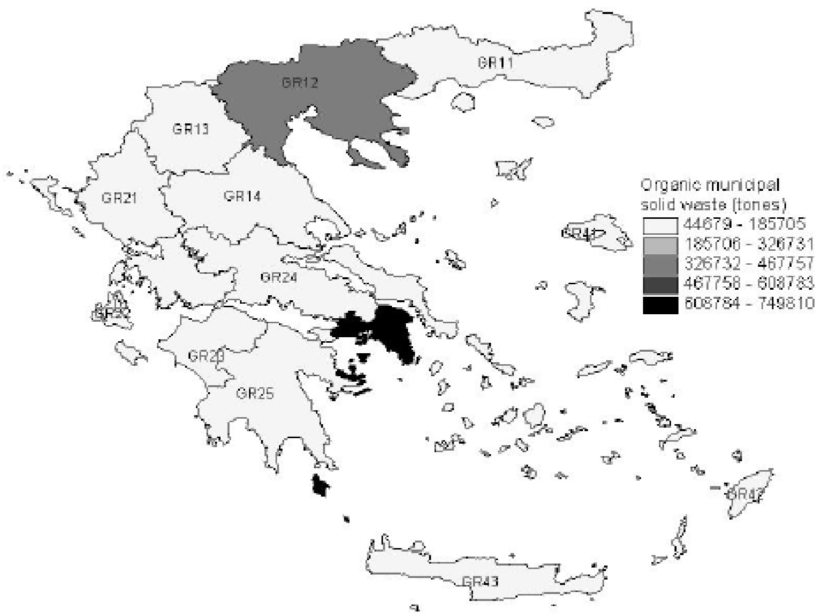

Figure 5: Organic Municipal Solid Waste

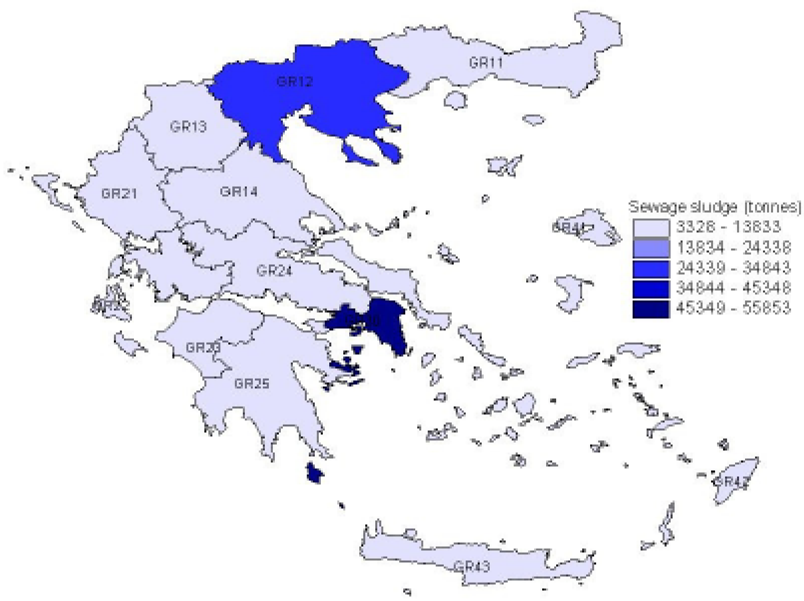

Figure 6: Sewage Sludge waste

4.4 Biogas potential

The main findings of Task 2.3 were the following:

- Only the theoretical potential based on total biomass production has been assessed in the frame of the project. The assessment of the biogas potential production is based on the assumption that the biogas plants will be mainly developed firstly based on organic wastes and then on energy crops.
- The yearly biomass production and corresponding theoretical biogas potential in the six target countries is presented in the following Table. The estimation excludes energy crops. Greece seems to have large potential for biogas production in terms of agricultural wastes (primary and secondary) and landfill gas.
- Based on the assumption that 30%[7] [8] [9] [10] of the organic wastes from agriculture and urban wastes can be used for biogas production this gives a result of 30TWh/year in the five countries (except Croatia).

REGIONS	SURFACE	BIOMASS PRODUCTION (tonnes * 10^3)						BIOGAS EQUIVALENT (m3*10^4)					TOTAL
NUTS	Ha*10^3	EC	AWPP	AWSP	OSW	SS	FPW	AWPP	AWSP	OSW	SS	FPW	GWh
SI005	26				18	0	6	0	0	358	3	145	30
SI00A	146				26	7	3	0	0	533	109	69	43
SI003	104				35	4	3	0	0	703	64	62	50
LV006	31				34	5	4	0	1	684	77	86	51
GR22	230	11	11	50	59	4	0	202	880	1204	66	0	141
SI001	134				96	37	1	0	0	1948	550	26	151
SI00D	268				97	15	26	0	0	1970	229	598	168
SI006	89				74	5	58	0	0	1502	73	1362	176
SI00B	233				93	12	45	0	0	1878	173	1058	187
LV007	1013	2516	110	29	16	5	9	2092	504	331	80	205	193
LV008	1526	3063	127	42	12	2	6	2416	743	251	29	131	214
LV003	1360	3562	137	37	11	8	14	2615	660	232	116	326	237
SI00C	104				165	55	31	0	0	3358	827	724	295
GR41	384	38	137	78	45	3	0	2606	1374	907	50	0	296
SI009	214				196	53	55	0	0	3975	796	1279	363
GR42	532	37	76	185	93	7	0	1446	3270	1886	104	0	402
SI002	217				188	53	120	0	0	3818	793	2822	446
LV005	1455	2965	117	46	14	4	233	2225	815	275	64	5466	531
SI004	238				350	95	57	0	0	7100	1431	1343	592
SI00E	256				293	90	122	0	0	5942	1343	2862	609
LV009	1074	8109	422	37	11	5	64	8061	651	220	69	1493	630
GR43	831	12	401	106	147	11	0	7659	1870	2984	164	0	761
GR21	916	107	107	649	72	5	0	2038	11461	1468	81	0	903
GR13	947	581	320	438	60	4	0	6116	7741	1218	67	0	909
RO32	182	840	311	14	335	11	90	5939	245	6793	165	2105	915
GR25	1551	83	500	226	135	10	0	9536	3988	2734	150	0	984
GR24	1555	341	542	253	125	9	0	10343	4464	2542	140	0	1049
GR30	381	19	81	79	750	56	0	1544	1393	15221	838	0	1140
HR1	867	5922	125	169	301	368	117	2380	2984	6118	5526	2746	1185
GR23	1132	352	416	547	150	11	0	7935	9666	3046	168	0	1249
HR3	2471	1074	19	27	419	512	163	360	477	8501	7677	3816	1250
HR2	2322	16438	404	272	245	300	95	7718	4799	4978	4496	2235	1454
GR11	1418	1247	899	762	124	9	0	17166	13449	2527	139	0	1997
GR14	1405	854	983	791	154	11	0	18761	13965	3117	172	0	2161
BG11	1029	1620	190	1561	221	10	20	3619	27561	4491	156	465	2178
RO12	3410	4757	721	189	381	681	102	13763	3329	7742	10217	2399	2247
BG23	1465	1459	267	2253	387	18	35	5091	39785	7859	273	814	3229
GR12	1917	1701	1300	1593	389	29	0	24821	28132	7902	435	0	3677
RO11	3416	7329	1825	229	411	850	110	34841	4045	8336	12749	2583	3753
RO42	3203	7882	2231	122	290	734	78	42588	2155	5890	11005	1825	3808
BG21	2031	663	219	2305	957	45	86	4177	40706	19430	676	2011	4020
BG12	1827	3836	378	2842	513	24	46	7216	50188	10422	363	1079	4156
RO21	3685	9676	2230	301	558	1028	150	42565	5319	11332	15419	3511	4689
RO41	2921	11743	3315	154	343	290	92	63287	2711	6960	4347	2156	4768
BG13	1997	5204	518	4368	616	29	54	9879	77135	12511	428	1274	6074
BG22	2752	1985	400	5320	867	41	78	7636	93947	17610	613	1823	7298
RO22	3576	16279	5332	165	442	696	119	120875	2917	8975	10441	2781	8759
RO31	3445	17738	6739	217	496	809	133	128656	3824	10059	12132	3117	9467
TOTAL	62283	140042	32906	26453	11815	7072	2424	628171	467157	239840	106082	56797	89883

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[7] Nielsen C., Larsen J., Iversen F., Morgen C., Holm Christensen B. (2005), Integrated biomass utilization system. Baltic Biorefienry Symposium, Aalborg University Esbjerg.

[8] Kim. S., Dale B.E., (2004), Global potential bioethanol production from wasted crops and crop residues. "Biomass and Bioenergy",Vol.26, 361-375.

[9] Sanders J., (2005) Biorefinery, the bridge between Agriculture and Chemistry. Wageningen University and Research centre. IEA Workshop: Energy Crops & Bioenergy, Utrecth, NL, 22.th ofSeptember, 2005.

[10] Robert D. Perlack, Lynn L. Wright, Anthony F. Turhollow, Robin L. Graham, et al. Environmental Sciences Division, Oak Ridge National Laboratory: Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply, 2005

4.5 Agricultural structure

Data for Greece are based mainly on the Agricultural – livestock census 1999/2000 and Agricultural - Livestock Survey 2006. The main results based on the the Agricultural – livestock census 1999/2000 are the following:

- In Greece there are 817,060 holdings with a total surface of 3,875,180ha
- In the interval between 0 and 2 hectares of agricultural area there are 394,950 holdings with an area of 440,020 hectares. The biggest cumulative surface is encountered for the interval 2-5 hectares with 797,380 hectares (226,500 holdings). The temporary crops are dominated by durum wheat (587,190hectares), soft wheat (157,420 hectares), cotton (382,800 hectares), industrial plants (476,360 hectares) and maize (183,320 hectares). The permanent crops are dominated by olive (737,160 hectares).
- The livestock is dominated by sheeps and goats (8,752,670 and 5,327,200 heads respectively). There are also 28,330 holdings with 652,390 heads of Cattle and 36,250 holdings with 969,850 heads of Pigs.

According to the Agricultural - Livestock Survey of 2006:

- The livestock was dominated by sheeps and goats (119,355 holdings with 9,031,645 heads and 123,348 holdings with 4,986,423 heads respectively). There were also 23,437 holdings with 684,057 heads of Cattle and 34,721 holdings with 1,055,057 heads of Pigs.
- There were 1,273 holdings in Central Macedonia with more than 50 Cattle and in Thessaly there were 735 holdings with more than 50 Cattle. At the same time there were 238 holdings and 127 holdings with more than 100 pigs in Thessaly and in Western Greece respectively (see **Tables 2** and **3**).

Table 2: Holdings with Cattle by region broken down by size classes, year 2006

Region	Total	1-2	3-5	6-9	10-19	20-29	30-49	50 and over
Total	**23.437**	**4.463**	**4.431**	**2.844**	**3.759**	**1.827**	**2.090**	**4.023**
East Macedonia and Thrace	5.053	1.120	1.215	732	728	312	350	596
Central Macedonia	4.966	582	720	540	819	462	570	1.273
West Macedonia	2.320	354	420	320	516	252	196	262
Thessaly	2.104	460	225	159	186	132	207	735
Epirus	1.327	216	156	105	153	89	182	426
Ionian islands	479	144	118	56	80	32	26	23
Western Greece	1.803	366	236	141	279	168	221	392
Central Greece	702	168	162	0	88	51	80	153
Peloponnese	1.089	306	256	150	172	64	69	72
Attica	115	30	18	14	20	5	12	16
North Aegean	979	170	252	168	210	96	60	23
South Aegean	2.218	435	584	435	468	152	99	45
Crete	282	112	69	24	40	12	18	7

Table 3: Holdings with pigs by region broken down by size classes, year 2006

Region	Total	1-2	3-9	10-19	20-29	30-49	50-99	100 and over
Total	**34.721**	**22.797**	**6.734**	**2.088**	**981**	**631**	**636**	**854**
East Macedonia and Thrace	1.826	1.194	404	0	66	60	36	66
Central Macedonia	2.431	1.330	480	225	212	0	72	112
West Macedonia	3.372	2.484	639	166	0	33	25	25
Thessaly	4.593	3.333	606	132	80	100	104	238
Epirus	879	531	164	46	18	23	18	79
Ionian islands	671	384	240	0	16	6	14	11
Western Greece	6.858	4.270	1.428	460	183	208	182	127
Central Greece	3.673	2.660	624	240	0	45	36	68
Peloponnese	2.191	1.510	405	128	48	36	24	40
Attica	318	152	84	28	8	14	10	22
North Aegean	2.176	1.413	504	160	48	30	18	3
South Aegean	2.529	1.392	640	272	98	76	43	8
Crete	3.204	2.144	516	231	204	0	54	55

5 Biogas purification and fed into to the natural gas grid

5.1 Natural gas grid

The introduction of natural gas into the Greek Energy System can by compared in magnitude with the electrification of the country. Natural gas is an effective and modern form of energy, environmental friendly and safe. The National Natural Transportation System (see **Figure 7**) is comprised of [11,12,13]:

- The central gas transportation pipeline (599km) which extends from Promachonas to Attica and from Thessaloniki to Kipoi .
- Transportation branches (566km) linking the various regions of the country (Eastern Macedonia and Thrace, Thessalonica, Platy in Imathia, Volos, Viotia, Inofyta, Attica). With the completion of the Korinthos project by the autumn of 2007 the transmission branches will extend 600 km. In 2007 branches towards Western Thessaly and Evia have begun (119km).
- The natural Gas Metering and Regulatingf Stations.
- The Gas Control and Dispatching Center.
- The Operation and Maintenance Centres (in Attica, Thessaloniki, Thessaly and Xanthi).

Source: DESFA, 2008

Figure 7: The Greek Natural Gas System

[11] DEPA (2006), Annual Report
[12] DEPA's site, www.depa.gr
[13] DESFA's site, www.desfa.gr

5.2 Characteristics of natural grid

Natural Gas enters Greece via high pressure pipelines. Their course continues through medium pressure networks (19bar) that deliver gas to industrial consumers, but also through low pressure networks (4bars) that provide door-to-door gas to domestic, commercial and industrial consumers.

The pipeline that crosses the Greek-Bulgarian border has a diameter of 28-inch and then connects to the Greek North-South central pipeline (Greek-Bulgarian border to Attica) which is a high-pressure pipeline (70bar) with a diameter of 28-inch too[14]. The 87 km long between Komotini, Alexandroupoli and kipoi and the transoportation branches linking the various regions of the country consist of high pressure pipelines.

Medium pressure networks have been developed and are still being developed in Attica, Thessaloniki, Larissa, Volos, Inofyta, Thiva, the greater of Halkida, Lamia, Platy in Imathia, Kilkis, Serres, Drama, Xanthi, Kavala. Alexandroupoli and Komotini. Low pressure networks have been developed and are still being installed in Attica, Thessaloniki, Larissa, Volos, Inofyta, Kilkis, Xanthi and Komotini. Medium and low pressure networks are expanding in areas like Central Greece and Evia, Eastern Macedonia and Thrace and Central Macedonia by the EPAs[13].

5.3 Technical requirements for biomethane injection into the natural gas grid

Natural Gas is a mixture of hydrocarbons in a gaseous form. It mainly consists of methane(CH_4), belonging to the 2nd Cluster of gas fuels. Regarding natural gases, a reference state has been defined, named «normal» state and to that state their quantities are reduced. This state is 273.15K (0^0C) as to temperature and 1.01325 bar as to pressure.

The Ministerial Decision (Y.A.) Δ1/1227/2007 "On the determination of the procedure for the conclusion, content and terms of agreements for the exercise of the right to access and for the use of the National Natural Gas System" (Officail Gazette 135/B/5.02.2007)" determines the content, the terms, and the procedure for the conclusion of Agreements for the Transfer of Natural Gas concluded for the exercise of the right to access and use the National Natural Gas System (Ε.Σ.Φ.Α. in greek) and in particular the part of the National Natural Gas System that constitutes the National System for the Transfer of Natural Gas (Ε.Σ.Μ.Φ.Α. in Greek).

5.4 Opportunities for biomethane injection

According to LAW No. 3428/27.12.2005 "Liberalization of Natural Gas Market" (Officail Gazette 313/A/2005) article 39:

"The use of Natural Gas Systems pursuant to the provisions of this law is also allowed for the transmission of biogas, gas produced from Biomass and other kinds of gases, provided that it is so possible from a technical point of view and the technical specifications are met, after taking into consideration the quality requirements and the chemical features thereof".

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[14] Ministry of Development (2007). 1st report for the long term Energy Policy in Greece 2008-2020, part 1, Athens August.

6 Biogas utilization

The next paragraphs summarizes the Task 2.6 report “Technical opportunities for the utilisation of biogas in Eastern Europe” submitted by Tobias Finsterwalder and Dominik Rutz.

6.1 Opportunities of biogas production

The opportunities for biogas production in the BiG>East target countries are very high, especially in the waste treatment sector. Implementation will enable efficient and environmentally sustainable waste disposal, while at the same time generating a significant amount of energy in a manner that aids the region’s responsibility to reduce and offset its carbon footprint. Generally, the countries involved have good infrastructure and framework for waste collection as well as lots of potential in growing energy cops or animal slurry.

There are adequate waste streams to support a variety of biogas technologies and the population density is such that economies of scale can be achieved. The biogas facilities can be distributed to map onto existing waste, industrial and agricultural facilities, thereby introducing very little additional transport costs. The countries in this region also have large agricultural sectors which provide both waste streams, and markets for biogas process by-products such as compost and liquid fertiliser.

Therefore with infrastructure and logistics largely in place, and with available waste streams and a healthy agricultural sector, the conditions are very favourable. Options for setting up facilities are numerous as they can be centralised or distributed as required.

6.2 Technologies

Adequate waste streams for biogas plants can include food waste from households, restaurants or supermarkets, garden waste, bio waste, cow and farm animal slurry, straw, sewerage, food processing waste and other industrial organic waste as well as non waste crop inputs such as maize and grass silage. Essentially all organic and biodegradable waste material can be used for biogas production.

Biogas systems using energy crops as feedstock are robust simple and reliable technology. Waste treating biogas systems are more complicated because of contaminants removal, but the working principle is the same. The organic material is broken down in large tanks in an anaerobic process resulting in the formation of methane gas which is then used as a fuel to drive an electric generator.

The spent slurry material at the end of the biogas process known as digestate can be separated into solid material which forms rich and productive compost, and a liquid rich in nutrients suitable for direct application to farm land as a liquid fertiliser.

6.3 Biogas utilization

In general, biogas is an energy carrier which can be used for several energy applications. This includes electricity generation, heat production, combined heat and power production (CHP), and transport applications. These technologies are described in the BiG>East Handbook which is available on the BiG>East website www.big-east.eu. Biogas upgrading to natural gas quality (biomethane) and feed-in into the natural gas grid is described in the BiG>East report "Biogas purification and assessment of the natural gas grid in Southern and Eastern Europe", also available at the BiG>East website. Anyhow, this technology is rather new and needs more development. Implementing the biogas upgrading technology can be only recommend in very special cases and in countries with existing experience in biogas production like in Germany where 22 biogas upgrading plants are currently being installed.

For the utilisation of biogas in the target countries, it should be feasible, that all systems and components can be constructed or installed by using domestic labour and engineering services. The technology should also be simple rather than sophisticated, since simple technologies are more robust, easier to maintain and better suitable for the local infrastructure in cases where it is at an early stage of development.

The most suitable system which should be implemented in the BiG>East target countries is a combined heat and power plant operating with combustion engines. The combined heat and power production technology is a well known, robust technology for the utilisation of electricity and heat. CHP generation from biogas is considered a very efficient utilisation of biogas for energy production. Before CHP conversion, biogas is drained and dried. An engine based CHP power plant has an efficiency of up to 90% and produces 35% electricity and 65% heat. An important issue for the energy and economic efficiency of a biogas CHP plant is the utilisation of the produced heat. Usually, a part of the heat is used for heating the digesters (process heating) and approximately 2/3 of all produced energy can be used for external needs.

Many biogas plants in countries with good feed-in tariffs for electricity and no incentives for heat utilisation, like in Germany, were established exclusively for electricity purposes, without heat utilisation. Due to the lost income from heat sale of these plants (and some other reasons like increased energy crop prices), many biogas plant operators in Germany had serious economic problems in 2007 and 2008. New biogas plants to be set up in the target countries should therefore always include heat utilisation in the overall plant design.

Biogas heat can be used by industry processes, agricultural activities or for space heating. The most suitable heat user is the industry, as the demand is constant throughout the whole year. Heat quality (temperature) is an important issue for industrial applications. The use of heat from biogas for building and household heating (mini-grid or district heating) is another option, although this application has a low season during summer and a high season during winter. Biogas heat can also be used for drying crops, wood chips or for separation of digestate. Finally, heat can also be used in 'power-heat-cooling-coupling'-systems. This process is known from refrigerators and is used e.g. for cooling food storage or for air conditioning.

7 Assessment of impacts

7.1 Environmental Issues

Air and Emissions

Athens is the best known case of urban air pollution in the country. Although the pollution episodes in rural areas are rare, Anaerobic Digestion is an important factor in GHG reduction and particularly CO_2, since biogas exploitation offers the opportunity of the substitution of fossil fuels. Especially in the case of optimal biogas exploitation the overall emissions effects from an AD plant is positive.

It is worth mentioning that although biogas is a potential low-carbon energy source, this depends on the way biogas is produced. In the case that biogas comes from residues, waste or from energy crops grown on abandoned agricultural land this offers sustained GHG advantages. On the contrary converting arable land to produce energy crops as biofuels creates a “carbon debt” by releasing more CO_2 than the total reduction that these feedstock provide by replacing fossil fuels (in a LCA basis). Thus, the environmental impacts and implication of biogas exploitation needs careful consideration and are site specific and oriented in a project base.

The revised Greek National Programme for Climate Change, estimates realistic CO_2 savings of 4.5 Mt CO_2-eq from the increased use of Renewable. Among others it is estimated that Anaerobic Digestion of pig manure (35% of the total breeding animals in 2010 and 50% of the total breeding animals in 2015 respectively) can reduce greenhouse gas emissions by 60,000t CO_2-eq in 2010 and 83,000t CO_2-eq in 2015.

According to estimates made by CRES[15], and based on a conservative scenario, it is estimated that the AD of manure and organic wastes from the slaughter houses and milk factories could feed CHP plants of total installed capacity of 350 MW and a mean annual electricity production equal to 1.121.389 MWhe/y. This means an indirect yearly CO_2 reduction by 729kt.

Odour is a site specific problem arising mainly from the feedstock management and storage into the biogas plant and the digestion process. Some of the recommendations for odour control measures are the limited storage time, the careful handling procedures, the use of odour control equipment where such devises are necessary and covered units.

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[15] Zafiris Christos (2007). Biogas in Greece. Current situation and prospectives. European Biogas Workshop proceedings “The Future of Biogas in Europe – III”, University of Southern Denmark Esbjerg, Denmark 14-16 June 2007.

Soil and Water

Concerning waste there are special provisions on the use of biological sludge from waste-water treatment plants in the agriculture (M.D. 80568/4225/91, which conforms to Directive 86/278/EC). M.D. 80568/4225/91 includes limits for heavy metal concentrations in sludge and total heavy metal quantity put on the ground, sampling and analysis methods, cases where use is prohibited, etc. In these MD there are also limits for the quantities of heavy metals that can be applied on farm land per year (mg/ha/year) in base of 10 years average.

According to the requirements of the EU Nitrate Directive 91/676/EEC (JMD 195652/1906/1999, OJG 1575/B), seven sensate areas toward nitrogen pollution from agricultural run-offs have been established (Thessaly plain, Kopaida plain, Argolida plain, Pinios basin, Thessaloniki plain, Strimonas basin, Preveza-Arta plain). In these areas the implementations of special Action Programmes has been planned and are obligatory to all the farmers of these areas.

In parallel, that animal manure, municipal sewage and agro-industrial waste can contain substances (bacteria, viruses, parasites, heavy metals, harmful organic substances) that can potentially be a threat to public health or the environment[16].

Landscape and land use

The Greek Special Framework for the Spatial Planning and Sustainable Development for the Renewable Energy Sources-RES[17] identify criteria and guidelines for the site allocation of RES projects, per RES category and type of geographic area. For biogas plants the most suitable sites are considered those located near to the «feedstock» production and availability. The Plan sets some general criteria in order to exclude some areas or land uses but doesn't recommend specific sites (eg. like in wind parks).

Proposals to use the surplus agricultural land for energy crops have open a big discussion, among others, about the negative effects on the agricultural landscape of Greece (eg. Reduction of biological diversity, high input of fertilizers and pesticides, visual impact, monoculture of certain crops and effects to the surrounding landscape). Till today it is seemed a more lasting solution the biogas exploitation from manure, residues and waste, sludge and agro-industrial residues and unsuitable plants for other purposes.

[16] European Parliament 2008. Report on sustainable agriculture and biogas: a need for review of EU legislation (2007/2107(INI)).

[17] Source: Hellenic Ministry for the Environment Physical Planning and Public Works

7.2 Socio-economic issues

Some of the social and economic aspects related to biogas exploitation in Greece are the following:

- Although the last decade new biogas plants were constructed and operated, there are still barriers which affect to biogas exploitation and deployment in Greece. Nevertheless, as the gas penetrates more and more to the Greek energy market the biogas production can contribute towards to energy diversification, security and efficiency.
- According to LAW No. 3428/27.12.2005 "Liberalization of Natural Gas Market" (Officail Gazette 313/A/2005) article 39: "The use of Natural Gas Systems pursuant to the provisions of this law is also allowed for the transmission of biogas, gas produced from Biomass and other kinds of gases, provided that it is so possible from a technical point of view and the technical specifications are met, after taking into consideration the quality requirements and the chemical features thereof".
- The new law for RES (law 3468/2006) is dedicated to the promotion of RES and set a tariff of 73€/MWh (€75,82/MWh for the year 2007) for biogas plants. Although higher electricity price must be examined based on the form of Biomass (there is no differentiation according to biomass form) this incentive guarantees a regular income for the plant owners.
- The implementation of a biogas plant can increase direct or indirect the jobs during the all project phases and lifetime (especially in the case of the construction and operation of a CAD plant). Even in the case of a small farm scale plant the part time employment of the farmer can give benefits and parallel new income opportunities.
- With over 56% of the population in the 27 Member States of the European Union (EU) living in rural areas, which cover 91% of the territory, rural development is a vitally important policy area. An energy scheme like a biogas plant contributes not only to the exploitation of local energy sources but also toward improving the quality of life in rural areas and encouraging diversification of the rural economy. This dimension is vital especially in Greece where the agricultural areas despite the development efforts continue to suffer from high unemployment rates and the young people continue to search jobs to the urban or semi-urban places or work in temporary jobs.
- A biogas plant must be adapted to the particular regions and must be accepted from neighbors and the general public. Thus apart form its economical and technological viability a biogas plant must have also "environmental and social compatibility" based on thorough examination of the project and public awareness and participation.

8 Conclusions and Outlook

The energy sector in Greece undergoing the last years significant changes due to the EU and national policies in the field of energy and environment (eg. full liberalization of the energy market and environmental protection). As a result the impact and effects of the implementation of these policies are not yet visible and especially for the near future (eg. energy price, energy mix). Lignite, the main domestic fossil fuel resource of Greece, it seems that will continue to play a major role in the country's fuel mix in the future, but further RES penetration is a necessity.

The promotion of RES in Greece is based not only to the great potential of the country but also to the state priority toward RES electricity and emissions reduction. Although today there is still heavy state involvement in the economy the policy for the future is the reduction of the role of the state and the further development of the market rules and financial-support schemes.

The new law for RES (3468/2006) is dedicated to the promotion of RES, sets a new environment in the electricity generation and among others, simplifies the licensing procedures, the guaranteed market price is increased (the new pricing tariff system for electricity production from RES and CHP systems set a tariff of 73€/MWh for biogas plants) while the licensing deadlines are being reduced. However, it seems that the situation for the attractiveness of new biogas investments has not been significantly changed until now.

During last years renewable development in Greece is positively affected by the country's very good resource potential and the state policy. The Legislative framework has significantly improved by the introduction of new RES and environmental legislation. However, although the legislative framework (eg. energy and environmental policy, EU and country commitments, new law for RE matters, etc) and the financial environment have changed the picture, so that new biogas plants were constructed and operated, there are still barriers (mainly no technological) which affect to further biogas exploitation and deployment in Greece (eg. public perception, experience and awareness mainly on farm scale and industrial biogas applications, lack of price for the heat production, licensing procedure, lack of «gate fees» for waste disposal, externalities like euthrophication, groundwater pollution, replacement of fossil fuels which are not assessed and monetized, price of the biogas-produced electricity, etc).