CODE2

Cogeneration Observatory and Dissemination Europe

D5.1 - Final Cogeneration Roadmap

Member State: **Greece**

November 2014

Leading CODE 2 Partner: Hellenic Association for Cogeneration of Heat and Power, HACHP

Greece is part of the non-pilot Member States of the SE Europe CODE2 Region.
The CODE2 Region 'South-East Europe' comprises the following Member States: Bulgaria, Cyprus, Greece, Romania

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Introduction and Summary

The CODE2 project[1]

This roadmap has been developed in the frame of the CODE2 project, which is co-funded by the European Commission (Intelligent Energy Europe – IEE) and will launch and structure an important market consultation for developing 27 National Cogeneration Roadmaps and one European Cogeneration Roadmap. These roadmaps are built on the experience of the previous CODE project (www.code-project.eu) and in close interaction with the policy-makers, industry and civil society through research and workshops.

The project aims to provide a better understanding of key markets, policy interactions around cogeneration and acceleration of cogeneration penetration into industry. By adding a bio-energy CHP and micro-CHP analysis to the Member State projections for cogeneration to 2020, the project consortium is proposing a concrete route to realise Europe's cogeneration potential.

Draft roadmap methodology

This roadmap for CHP for Greece is written by CODE2 partner HACHP, based on a range of studies and consultations, with local experts and energy players, through a process of discussion and exchange of ideas and opinions on the promotion of CHP in the country.

Acknowledgement

HACHP and the CODE2 team would like to thank all experts involved for their contributions to develop this roadmap, which has been valuable regardless of whether critical or affirmative. It has to be stressed that the statements and proposals in this paper do not necessarily reflect those of the consulted experts.

Summary

Greece has one of the lowest percentage of cogenerated electricity among EU member states, although it has a 40-yr tradition on CHP, initially in the industrial sector.

Today the installed CHP capacity is steady for the past five years, about 570 MW_e, covering mainly industrial and tertiary sectors. The appropriate legal framework is in place, for the promotion of CHP, along with supporting mechanisms for independent producers, but Greece is lagging of long-term stability and complexity in legislation (i.e. frequent changes of energy laws, amendments) and bureaucracy in the procedures that prevents any investor for acting.

A key factor for the promotion of CHP, in Greece, is the existing energy prices, i.e. rather high gas price – one of the highest in EU, which along with the current economic recession makes any CHP investment more difficult. Also the recent revision of the feed-in-tariffs to lower ones for cogenerated electricity injected to the Network affects seriously the viability of the existing CHP units.

According to studies, performed before the recession, there is sound economic potential in different sectors of the economy for cogeneration, i.e. industry/DHS, in tertiary sector (hospitals, hotels) that can be financed by EU-funds (CSF) and in micro-CHP.

The roadmap path would deliver 11.1 TWh/annum of primary energy saving (PES) under the EED methodology. Considering the likely implementation path of such, a roadmap of 24 TWh/a in PES and 14 million tonnes of CO_2 reductions are achievable in practice.

[1] For more details and other outcomes of the CODE2 project see: http://www.code2-project.eu/.

1. Where are we now? Background and situation of cogeneration in Greece

1.1 Current status: Summary of currently installed cogeneration

In Greece, cogeneration has a 40 years tradition, initially in industry. Today, the installed CHP capacity remains constant for the past five years, covering mainly industry and tertiary sector.

In Greece, most of the recent cogeneration plants were built in early 70s, in the industrial sector i.e. food processing (sugar), textiles, paper and pulp, steel, refineries, chemical, etc., without any state economic incentives. All cogenerators were auto-producers and the main fuels were oil and oil products, as no NG was available during that period. Table 1 presents the different industrial sectors with CHP, with an installed capacity of 346.3 MW_e, for 1985.

Industrial Sector	MW_e	%
Refineries	93,50	27,00
Steel	80,00	23,10
Food processing	56,00	16,17
Chemical	47,80	13,80
Pulp & paper	43,05	12,43
Textile	14,35	4,14
Aluminum	11,60	3,35
Total	**346,30**	**100,00**

Table 1: CHP in industry, (1985)

Table 2 presents the two cogeneration units in the tertiary sector in Greece, during the above-mentioned period, as dissemination projects financed through EEC funds. It should be noticed that the 2nd one was the first tri-generation unit in Greece.

Nr.	Name (city)	Type of CHP Unit	Installed Power (kW)		
			Electrical	Thermal (winter)	Cooling (summer)
1.	Solar Village in Athens	Diesel	67	72	—
2.	American College of Athens	Diesel	320	380	265

Table 2: CHP installations in tertiary sector until 1999

In 1995, the de-industrialization of the country has started and many industries operating in cogeneration mode went out of operation, for different reasons, i.e. the changes in the economies in E. Europe after 1989, affecting Greece, textile sector vanished from Greece, due to the strong competition from E. European and SE Asian companies, bankruptcies, companies moved to neighboring countries for lower wages and taxation, etc. So, as a result, the installed industrial CHP capacity declined. Table 3 presents the different industrial sectors operating with CHP, with an installed capacity of 116.1 MW_e for 1995.

Industrial Sectors	MW_e	%
Refineries	93,50	80,53
Aluminum	11,60	9,99
Chemical	11,00	9,47
Total	**116,10**	**100,00**

Table 3: CHP in industry, (1995)

In the beginning of 21st century, the situation for the development of CHP was improved, in terms of legal certainty and fuel supply, due to the adoption of the Law 2773/99, implementing the electricity liberalization Directive and the relevant developments in the planned gas infrastructure[2].

Table 4 shows the new installed capacity for CHP at 168.16 MW_e, with attention to the CHP installations in tertiary sector (hospitals, Universities, etc.) and CHP units in six different municipal water companies all over Greece, working mainly with landfill gas. Many of these installations were financed through EU-funding (CSF), operating in Greece during that period.

Industrial Sector	MWe	%
Refineries	93,50	55,60
Aluminum	11,60	6,90
Steel	11,50	6,84
Chemical	11,00	6,54
Food	4,50	2,68
Metal	2,72	1,62
Brick	1,13	0,67
Textile	1,10	0,65
CHP with landfill gas	25,91	15,41
Tertiary sector	5,20	3,09
Total CHP	**168,16**	**100,00**

Table 4: CHP installations in Greece, (2005)

Today, the previously described situation has changed in many of the above-mentioned parameters; Greece is now supplied with NG from 3 different entrance points, the State is equipped with strong legal framework for cogeneration and the monopolistic electricity utility, PPC, is under structural changes, leading, at the end, to privatization.

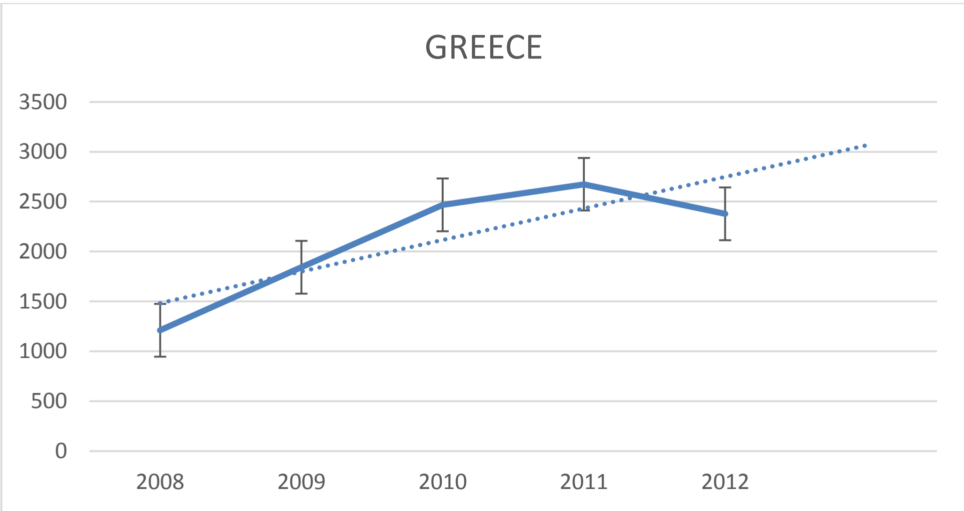
Table 5 shows the CHP statistics for Greece, based on Eurostat data, for 2006 -2012[3].

[2] SAVE XVII/4.1031/P/99-"Future Cogen" Project, Final Report
[3] Eurostat, http: //epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin= 1&language=en&pcode= tsdcc350

Year	CHP electricity generation TWh	Main activity producers	Auto-producers	Share of CHP in total electricity generation	CHP Electrical capacity, GW	CHP Heat production PJ	Main activity producers	Auto-producers	CHP Heat capacity GW
2012	2.40	6.9%	93.1%	3.9%	0.57	13.0	45.5%	54.5%	0.9
2011	2.67	11.6%	88.4%	4.5%	0.59	13.8	55.2%	44.8%	0.8
2010	2.48	6.8%	93.2%	4.3%	0.59	12.7	55.4%	44.6%	1.0
2009	1.84	10.1%	89.9%	3.0%	0.51	10.8	28.6%	71.4%	0.8
2008	1.20	100.0%	0.0%	1.9%	0.40	9.0	100.0%	0.0%	:
2007	1.02	100.0%	0.0%	1.6%	0.22	9.5	100.0%	0.0%	:
2006	1.05	20.0%	80.0%	1.7%	0.25	8.3	28.3%	71.7%	:

Table 5: Cogeneration data for Greece, for the period 2006-2012

From the Table 5, it can be seen that the majority of the cogenerators are operating as auto-producers (93%) and the remaining as “independent producers” (7%).



Cogenerated Electricity, in GWh, for 2008-2012

According to the Hellenic Operator of Electricity Market, LAGIE, during the years 2008–2010, the technical data of the “main activity CHP producers” injecting cogenerated electricity to the network[4] rewarded for their HECHP with a “F-i-T”[5], analysed in later section, is shown in Table 6.

Year	Installed CHP capacity, MW	Cogenerated electricity, MWh	Contract-based HECHP, MW
2008	98.73	34,792	56.28
2009	133.07	144,122	97.07
2010	134.71	114,560	98.71
2011	101.07	141,638	-[6]
2012	89.32	148,858	-

Table 6: Data for HE cogenerated electricity, by main activity producers, for 2008-2012

[4] Monthly bulletin regarding the Feed-in-Tariffs for RES and HECHP; www.lagie.gr
[5] Set by Art. 9 of L.3468/2006
[6] “Since 2011, all the measured installed CHP capacity is considered to be contract-based only. The rest cogenerators are considered to be inactive auto-producers” according to LAGIE.

The difference between the two data (Tables 5 and 6) is that the data in Table 6 deals only with cogenerated electricity from High Efficiency CHP units and does not take into account the cogenerated electricity by non-HECHP units or auto-producers.

As a result of the economic recession, started in 2010, many cogenerators closed down their installations, due to their financial difficulties to pay off their NG bills to DEPA[7] and to a more than six month-delay from the Operator of Electricity Market, LAGIE, to pay off the cogenerators for the cogenerated electricity injected to the Network or Grid. This situation worsened the following years, with a delay of more than 8 months, creating serious cash-flow problems to the cogenerators.

Analysing the current cogeneration market, the Hellenic Association for Cogeneration of Heat and Power-HACHP-has conducted a detailed study, in 2011, on behalf of the Centre for Renewable Energy Sources, CRES, which is the national entity for the promotion of RES and Energy Efficiency, by recording all installed HECHP units, operating as independent producers, in or out of operation, above 50 kW_e and the results are shown in Table 7.

HECHP units above 50 kW_e	
Total installed Capacity	101.07 MW_e
Industrial sector capacity	90.59 MW_e
Tertiary, other	10.48 MW_e

Table 7: HECHP units above 50 kWe, in Greece

Table 8 presents some CHP installations in operation, from all sectors, in Greece, of different installed capacities (micro- or small-scale or large industrial units), working either as independent producers, or auto-producers or competing to the day-ahead market.

No	Name	Area of installation	Capacity MW_e	Fuel	Sector	Status
1	Aluminium of Greece	Aspra spitia Viotia	110	NG	Industry	From 1/2008 to 12/2012 in monitoring phase until Jan 2013 when the permit was given. The permit has been issued by YPEKA in April 2014.
2	Thessaloniki Refineries	Thessaloniki	5.9	Ref. gases	Industry	Operating
3	Psyttalia island – EYDAP	Psyttalia Athens	5X2.4=12	Biogas	Athens Sewage & Water Co	Operating
4	Two greenhouses[8]	Alexandria & Drama	2x4.9=9.8	NG	Agriculture	Operating

[7] HACHP data.

[8] Equipped with flue gas treatment and using installations for CO_2 enrichment of greenhouse crops.

5	8th floor apartment building	Thessaloniki	0.004	NG	Tertiary	Missing agreement for connection to the national electricity grid[9] - in operation

Table 8: Notable Projects with HECHP units

Regarding district heating, the sector in Greece is developing slowly and not widespread. There were four DH systems in 90s; 3 in Northern Greece and 1 in Peloponnese of a total installed thermal capacity of 177 MW_{th}, when Public Power Co, PPC, has converted some coal-fired power stations into cogeneration mode for supplying heating to near-by cities and its previous negative behaviour toward cogeneration became much more positive.

Nr	City	Thermal Capacity of the DHS (MW_{th})
1.	Kozani	67
2.	Ptolemais	50
3.	Amyntaio	40
4.	Megalopoli	20
	Total	**177**

Table 9: DHS in Greece, in 90s

Later on, one private DH Company in Serres, N. Greece, with capacity of 4x4=16 MW_e cogeneration units, provides heating for 12900 households, operating from 2007. A new DH system, of a thermal capacity of 70 MW_{th} is scheduled to be in operation by 2015, by PPC, in Florina, a city in northern Greece with harsh winter conditions and will provide heating for 2300 households[10].

1.2. Energy and Climate Strategy of Greece

Greece is considered as a carbon-intensive country. Its electricity production is based mainly on lignite and NG (72%) and on RES for (17%). Greece transposes all Directives regarding Energy and Climate Change and is working towards a coherent policy on energy security, promotion of energy efficiency.

Greece is strong relied on oil and lignite and is characterized as a carbon-intensive country and oil use is high in all end-use sectors. Public Power Co -PPC- dominated 75.1% of the wholesale electricity market and more than 90% of the retail market[11]. PPC is obliged to sell electricity to end-users at regulated tariffs that often do not reflect costs. The supply sources of natural gas are already diversified, as Russian gas is imported through the Greek-Bulgarian entry point, while the Greek-Turkish entry point allows Greece to import gas from the Middle East and the Caspian region. Greece also receives LNG, mostly from Algeria on long-term contracts, as well as additional volumes from the spot market. The natural gas sector has traditionally been state-controlled, but a market reform is started since April

[9] Missing the official agreement between the AEDN and the cogenerator, for the connection of the unit to the Network, for selling the cogenerated electricity.

[10] Municipality of Florina: http://www.cityoflorina.gr

[11] Eurostat data (2010).

2010. Additionally, Greece has significant potential in almost all RES, but, especially, in PV installations, where the installed capacities, in MW, are increased by 130% from 2008-2012.

The entity responsible for Energy and Climate Strategy is the Ministry of Environment, Energy and Climate Change, YPEKA, which has been established in 2010, in order to confront the continuous environmental retreat and to promote further penetration of RES to the system and Energy Efficiency, the gasification of the electricity sector and the security of supply of the country. The target set by EU, regarding CO_2 emission for 2010, had an increase of 25%, compared to 1990's emissions, while there was finally an increase of only 12,6%, after revision[12]. Most of the targets set by the EU concerning climate and energy package are reached, not as a result of applied policies, but as a result of the reduction of energy consumption by the end-users, a result of the recession. The Ministry of Environment, Energy and Climate Change, YPEKA, in order to achieve its mission, has developed a strategic plan[13] based on 4 pillars amplified into strategic objectives. According to the strategy plan in order to deal with climate change, the actions chosen will need to entail a change of the current development model towards to a more sustainable low carbon economy. This will be achieved, among other actions, through energy efficiency that cogeneration provides. The most relevant pillar to cogeneration is No 1, which is dealing with "Combating Climate Change", moving towards to a competitive economy of low carbon consumption. The strategic objectives of Pillar 1 are:

- Improve energy efficiency: cogeneration plays one of the most important roles toward this target.
- Increase the share of Greece's energy use from renewable sources and natural gas, whilst ensuring the reliability of energy supplies. Cogeneration systems, using RES/NG, as fuels are part of this objective.

More analytically, the strategy axes of pillar 1 are:

- Energy savings for industry, transport, buildings and residential sector:

The penetration of cogeneration in industry, although low compared to other M-S, has already shown important results. An effort towards the increase of cogeneration in building sector is made through the obligation, where by 31/12/2019 at the latest, all new buildings should meet all their needs for primary energy from energy supplying systems based on RES, cogeneration plants, district or block heating systems, as well as heat pumps[14]. Also, the building energy efficiency certificate indicates, among others, the important role of cogeneration systems in order to improve their energy classification. A Technical Directive of the Technical Chamber of Greece, TCG, adopted by YPEKA, was issued in 2012, titled **"Micro- and Small-scale Cogeneration in buildings"** and it is used as an information tool to the building energy auditors, architects and engineers, showing the benefits of cogeneration and provides methodologies for designing a cogeneration installation in tertiary sector, up to 1 MWe.

- Establishment of national targets for the penetration of energy generated from RES, the reduction of greenhouse gas emissions and energy saving. There are specific objectives concerning cogeneration using RES as fuel shown on Table 10, with their projective CHP contribution.

[12] Eurostat data
[13] http://www.ypeka.gr/Default.aspx?tabid=230&locale=en-US&language=el-GR
[14] L.3851/2010.

Estimation of total contribution (installed capacity, gross electricity generation) expected from each renewable energy technology								
	2005		**2010**		**2015**		**2020**	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydro	2407	4424	2536	4211	2915	4910	2951	4873
Geothermal	0	0	0	0	20	123	120	736
Solar	1	0,9	184	242	1300	1754	2450	3605
Wind	491	1267	1327	3129	4303	9674	7500	16797
Biomass solid	0	0	20	73	20	73	40	364
Biogas	24	94	40	181	100	431	210	895
TOTAL	2923	5786	4107	7838	8658	16965	13271	27270
of which in CHP	**-**	**-**	**20**	**73**	**20**	**73**	**40**	**147**

Table 10: Estimation of total contribution expected from each RE technology[15]

A growth is expected in tertiary sector, with attention to public and private hospitals. Also, many hotels, mainly in Athens and Thessaloniki area, are applying for the required permits for CCHP (trigeneration), which can be a time-lengthy process, especially, if an environmental permit is required.

As of micro-CHP applications (see Annex3), are mainly installed in the residential sector, there was a notable growth in the years before crisis, but now, this was declining, due to the high investment costs.

Additionally, the National Energy Planning Committee, in 2012, submitted the "*Energy Roadmap for 2050*". This Roadmap states "*cogeneration plays a necessary and important role to national energy efficiency and is an essential factor, in order Greece to fulfil the target concerning the reduction of* CO_2 *emissions*". The Roadmap contains several scenarios about the development of electricity capacity of Greece. All of the scenarios refer to cogeneration as an essential factor, while in one of them distributed cogeneration industry stations will be constructed, using as fuel biomass, biogas and NG.

1.3. Policy development

There has been government involvement for the development of CHP in Greece, by creating the appropriate legal environment and by introducing support mechanisms for cogenerated electricity.

1.3.1. Legal policy towards CHP/HECHP

Until June 2006, Law 2244/94 set out the legal framework for cogeneration in Greece. This law, titled "*Regulation of issues regarding electricity production from RES and other conventional fuels*" came into effect in October 1994, and introduced the distinction between "auto-producer" and "independent producer" to the Greek energy market and allowed the installation of cogeneration plants by auto-producers (autonomous or connected to that period PPC-owned grid). Directive 2004/8/EC sets the framework for the promotion of cogeneration and especially high-efficiency cogeneration, a key factor towards the fulfilment of energy efficiency EU targets. Greece transposed the 2004/8/EC Directive into

[15] National Renewable Energy Action Plan, in the scope of the Directive 2009/28/EC.

the Greek legal system with L.3468/06, titled "*Promotion of Cogeneration two or more useful forms of energy, and other provisions*". L.3851/2010 (Article 10) requires that, by 31/12/2019 at the latest, all new buildings should meet all their needs for primary energy from energy supplying systems based on RES, CHP plants, district or block heating/cooling systems, as well as heat pumps. This obligation shall apply to all new buildings housing services of the public and wider public sector, by 31/12/2014 at the latest. L.4001/2011, transposes into national legislation, the third Internal Energy Market Directive. Among others, it stipulates the unbundling of the system operators and enhances the role of the independent regulator, regarding security of supply, licensing, monitoring of the market and consumer protection, cancelling the 35 MW_e threshold barrier, as the upper limit installed capacity for a cogeneration unit to be characterized as "High Efficient" one and be suitable for F-i-T. In early 2013, YPEKA issued a Ministerial Decree for the license and permit procedures required for both HECHP and non-HECHP units, solving long-due problems in cogeneration permits and making easier the investment environment. In 7.4.2014 the L.4254/2014, titled "*Measures to support and develop the Greek economy in the application of Law 4946/2012*" where some articles are referring to feed-in-tariff policy for RES and HECHP. A detailed analysis of the articles, with reference to HECHP, are discussing in details in later sections of this Roadmap. Important reference points of this Law are the arbitrary cuts of the F-i-Ts for HECHP, without any in-depth analysis of the CHP sector, the reset of the 35-MWe threshold, which was cancelled in the previous energy Law (L.4001/2011) and the introduction of CHP categories that they do not actually exist in the world CHP market. (i.e. < 1 MW_e gas turbine combine cycle, with heat recovery).

1.3.2. Support mechanisms for CHP/HECHP

Promotion of HECHP plants has been supported by several **support mechanisms**, including investment subsidies granted within the framework of EU-funded "*Operational Programmes on Competitiveness and Entrepreneurship*" and of the national investment law, or by tax exemptions. The same actions aimed at providing financial aid are still in effect, with assistance from the activity of Energy Service Companies (ESCOs). *L.3908/2011 "Private investment aid for economic growth, entrepreneurship and regional convergence"* has provided for supporting investment plans, including construction of HECHP plants, by offering (a) income tax exemption; (b) subsidy consisting in payment by the State of an amount of money, free of charge, for covering part of the subsidised expenditures; (c) financial lease subsidy consisting in coverage by the State of part of the instalments paid for the acquisition of mechanical and other equipment.

The EU-funded Operational Programmes: "*Environment and Sustainable Development*" and "*Competitiveness and Entrepreneurship*", part of the National Strategic Reference Framework (NSRF) 2007-2013, are financing several investments referring to cogeneration systems, as eligible expenditures, in the following programmes:

- "*High efficiency cogeneration of heat and power in hospitals*" aiming of installing HECHP units in conjunction with cooling systems using NG in hospitals; of a budget of 15 million €;
- "*Green Tourism*" aiming at supporting tourist establishments with a view to improving their operating infrastructures and operational procedures, in a greener direction and in its actions include the installation of cogeneration systems. The funds offered are approx. 30 million €;
- "*Alternative Tourism*" aiming at supporting investment plans including the development of one or more specific and/or alternative forms of tourism, and its actions include the installation of energy saving, cogeneration and generation systems from RES (of a total capacity of up to 20

kW$_e$ only for meeting own needs), under an "auto-producer" regime. The funds provided for are approximately 20 million €.

- Furthermore, a call for proposals has been published for financing district heating actions, either through new projects or by expanding existing networks as part of the Operational Programme "*Environment and Sustainable Development*", of a total budget of 50 million €.

1.4 Exchange of information and awareness

In Greece, the cogeneration technology was developed during 70s, but still is showing limited level of awareness. During the last years, an increasing trend in awareness is provoked by political decisions towards energy efficiency and emission gas reductions. Crucial roles play the EU Directives; on for HECHP and the other for EED for the promotion of CHP.

The Greek cogeneration market is still at its early stage of development, showing a limited level of awareness. Also, the challenges of the Greek energy market add to the difficulty of developing proper market awareness: the electricity market is still only partially liberalized; there are many distortions in both electricity and fuel markets, and, there are barriers, in both the legal and administrative area to overpass. Nevertheless, specific socio-economic actors trigger an increasing trend in awareness. Sales of cogeneration to customers rely on a commercial proposition and a functioning market for the application of cogeneration. The policy intervention of the EU to support cogeneration and assist the removal of market barriers is an important element of creating a good commercial proposition. However, by itself, it will not be sufficient to improve sales of cogeneration, if the customers are unaware or lacking support or if the supply chain skills and suppliers does not exist.

Final buying decision by a customer is the result of a set of complex interactions, involving the supplier, the supply chain and the customer. External conditions influence the process, as do the market structure and the policy structure. A mature market for a product is characterized by a high degree of awareness among all the relevant players in the market and ongoing buying and selling activity.

An assessment of awareness of cogeneration among key market actors has been developed. Using qualitative interview techniques with experts and market participants, four groups of the socio-economic actors for cogeneration were assessed.

The four groups and their sub-sectors are shown in Figure 1. The list is not exhaustive but contains all the most relevant players.

- Customers: utilities (& DH), industry, and potential users.
- Market and supply chain: installation companies, energy consultants, architects, technology and equipment providers, banks/leasing, ESCOs.
- Policy structure: energy and climate legislators and all levels of government.

- Influencers: media, general public, academics, environment NGOs, associations, planners, energy agencies.

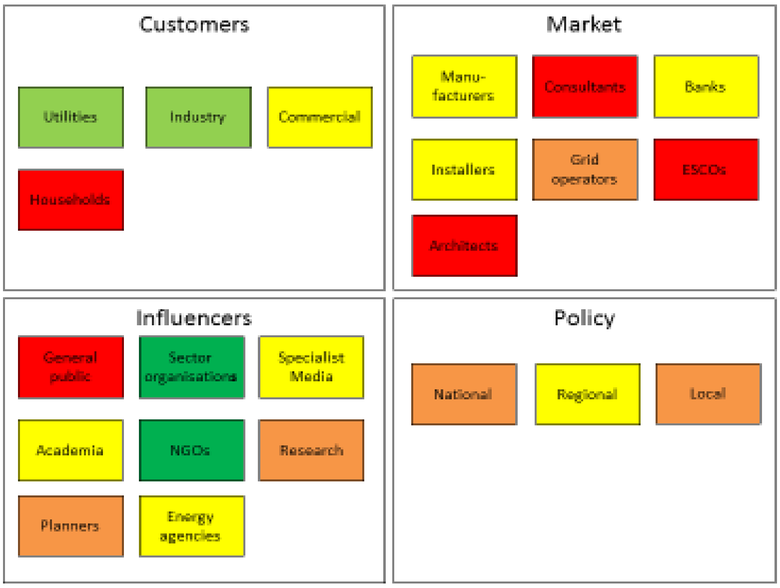


Figure 1: Awareness of CHP in the main socio-economic groups

Among the socio-economic groups, the policy makers appear to hold a low level of awareness. They are implementing the legislative framework regarding cogeneration, but, in reality, this is done only because they have to fulfil the requirements of an EU M-S and not because they are aware of the benefits of CHP. This is a conclusion, analysing their policy towards CHP during the past years.

Also, market and supply chain do not have the required awareness required for a more intense development, confirming the absence of the presence of manufacturers in the national market. Customers are divided in two opposite categories. Industries and utilities are aware of cogeneration technologies while SME's and households almost ignore them. Influencers are in general in an early awareness stage, excluding NGO's and sector organizations that already play a key role in awareness rise. Now, it is clear, that due to the influence of the EU Directives, the target set by EU for the 20-20-20 Energy strategy for 2020 that the country should fulfil, and due to the influence of HACHP in the energy community, the cogeneration position is clearer, stronger and seems more positive for the future. The importance of awareness in cogeneration is an essential factor in the dissemination of cogeneration systems on a national level. Proper and thorough information produces well-informed investors. At the same time a total rise of awareness may trigger an increase for investors to enter the market by installing cogeneration systems.

1.5. The economics of CHP

The key parameters – energy prices – for the financial viability of CHP projects show that the conditions are, currently, unfavorable for these investments, in the current economic environment. Also, current changes in the support mechanisms for CHP independent producers worsen further the operation of existing CHP units.

1.5.1. Main Energy Data concerning CHP

Key parameters for CHP economics are the local applied energy prices – electricity and gas prices – for industry and household/tertiary. So, the electricity and Natural Gas prices and the calculated "spark power ratio" for four consecutive years (09-12) are shown on Table 11 and Table 12.

Price/Year	Natural Gas, €/MWh			Electricity,[16] €/MWh	
	Industry above 1MW[17]	Industry up to 1MW[18]	Household	Industry	Household
2009	-	38	38	94	105
2010	-	43	45	85	97
2011	48,73	55	59	91	102
2012	48,56	63	68	100	106

Table 11: Natural Gas & electricity prices in Greece

Price/Year	Spark ratio		
	Industry above 1MW	Industry Up to 1MW	Household
2009	-	2,47	2,76
2010	-	1,98	2,26
2011	1,87	1,65	1,85
2012	2,06	1,59	1,68

Table 12: Spark ratio

Regarding NG, only a deduction of 4.5–7.5 €/MWh is made for small-scale and micro-CHP, by the local operating Gas Companies. The smaller in capacity the cogeneration installation is, the closer to 7.5 €/MWh deduction threshold it reaches. With this deduction the spark ratio for 2011 is 2.4 for households and 2.3 for industries, which are close to the threshold of 2.5.

Figure 2 shows the variation of spark ratio for households and industries, for the period of 2009 - 12.

[16] Eurostat.
[17] Data from an Industrial CHP user
[18] EPA Attiki

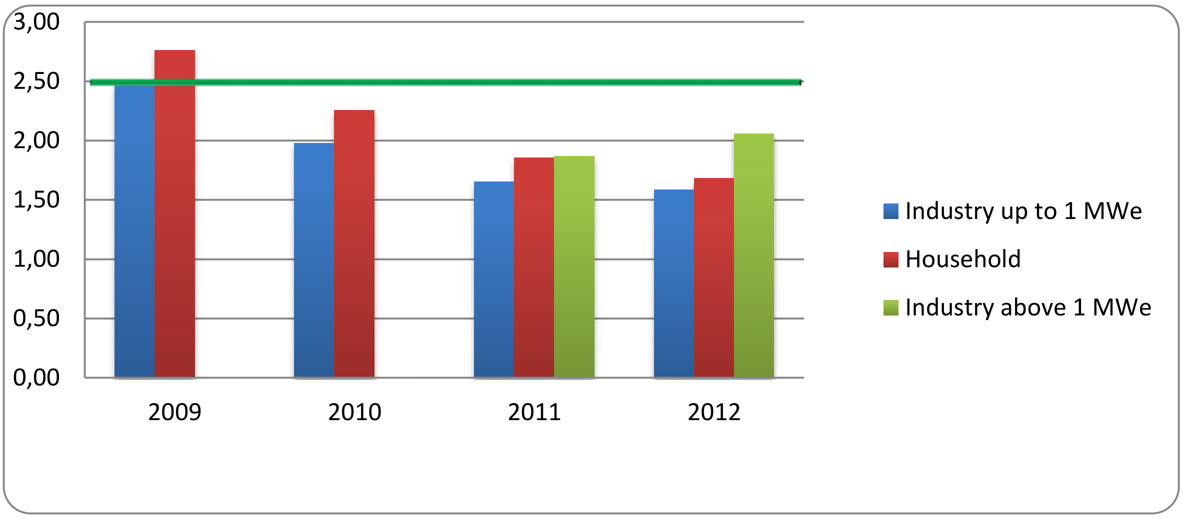


Figure 2: Variation of spark ratio for households and industries

1.5.2. CHP Economic matrix

The following matrix provides an overview of the economic situation of CHP in the main market segments.

Greece	Micro		Small & Medium		Large		
	up to 50kW		*up to 10 MW*		*more than 10 MW*		
	NG	RES	NG	RES	NG	Coal	RES
SME/Industry	Normal (green)	Normal (green)	Normal (green)	Normal (green)	Normal (green)	Poor (red)	Normal (green)
District heating/cooling	Not applicable (grey)	Not applicable (grey)	Normal (green)	Normal (green)	Normal (green)	Modest (yellow)	Normal (green)
Services	Normal (green)	Normal (green)	Normal (green)	Normal (green)	Normal (green)	Poor (red)	Normal (green)
Households	Normal (green)	Poor (red)	Not applicable (grey)	Not applicable (grey)	Not applicable (grey)	Not applicable (grey)	Not applicable (grey)

Legend:

- (green) **"Normal"** — CHP Investment has **good economic benefits**, return on investment acceptable (8-10%) for the investors, **interest for new investment exists**; there are no significant economic barriers for the implementation.
- (yellow) **"Modest"** — CHP Investment has **modest/limited economic benefits** and return on investment (5-7%), **limited interest for new investments**.
- (red) **"Poor"** — CHP Investment has **poor or negative return on investment or is not possible due to other limitations, no interest/possibilities for new investments**.
- (grey) **Not applicable** for the sector

1.5.3. Support mechanisms for "independent producers"

In Greece, the supporting scheme is provided, by Law, to the "*main activity CHP producers-independent producers*" through ***guaranteed feed-in-tariffs, F-i-T,*** only for the High Efficiency cogenerated electricity fed into the System or Grid, including the Grid of the Non-Interconnected Islands, on the basis of a defined price, expressed in €/MWh of electricity of a definite time period.

L.3851/2010, Article 5, defined the F-i-Ts for cogenerated electricity injected to the Network or Grid at 89.97 €/MWh for the interconnected network and 101.85 €/MWh for the non-Interconnected Network (islands), produced by **all** fuels, except natural gas (F-i-T, 3/2014). For those units using NG, a fuel clause coefficient (CC) was introduced to adjust the price of cogenerated electricity generated by HECHP plants in accordance with natural gas prices. The «F-i-T» for electricity from HECHP plants, using NG, was set as at 89.97*CC, for the interconnected System and 101.85*CC for the non-Interconnected Islands (€/MWh).

The NG CC is calculated by the following equation: $CC = 1 + (ANG - 26) / (100 \times n_{el})$ (1)

where: ANG is the average monthly price of natural gas for cogeneration, in €/MWh of gross calorific value, sold to natural gas users in Greece, excluding power generation customers. The price is set by YPEKA and communicated to LAGIE on a monthly basis. n_{el} is the electrical efficiency of an HECHP system in accordance with the gross calorific value of natural gas, which is set to 0.33 for HECHP units of an installed capacity of less than or equal to 1 MW_e and 0.35 for HECHP units of an installed capacity of more than 1 MW_e. The value of the clause coefficient may not be lower than one.

RAE Decision 435/2011 stipulated that the clause coefficient (CC) used to set the price of cogenerated electricity from HECHP producers who have realised investments in flue gas treatment and utilisation installations for CO_2 enrichment in greenhouses must be modified in accordance to the following equation: $CC = 1.1\ 8 + (ANG - 26) / (100 \times n_{el})$ (2)

This «premium» was determined on a monthly basis in accordance to the ANG of the previous month. The adjusted prices applied to the electricity generated by HECHP plants to which priority has been given by the Operator in allocating the load. The electricity sale contract executed between a cogenerator and the System Operator is valid for a period of 20 years.

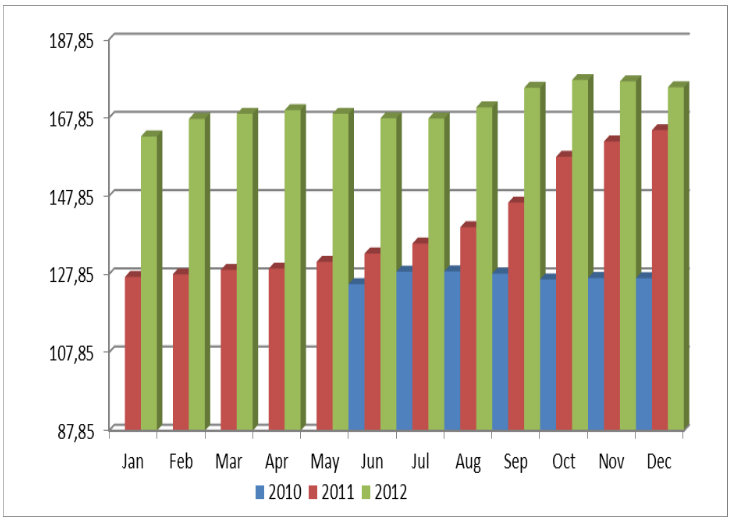


Figure 3: Monthly F-i-Ts for HECHP for units above 1 MW_e

The Feed-in-Tariff support scheme provided an acceptable economic environment for HECHP investments with a foreseen 11-13% return on investment mainly for those using NG fuel, in spite of unfavorable economic situation of Greece (Figure 3). It is important to mention that before the start of the economic recession of Greek economy, i.e. up to 2009, the rate of return of a HECHP investment, with NG fuel was around 18-20%.

L.4254/2014 updated L.3851/2010 (Article 5) and it introduces new formulae to calculate the «F-i-T» for all RES and for HECHP, aiming to eliminate, in short period, the debts of Greek Energy Market Operator-LAGIE. Now, the F-i-T for cogenerated electricity injected to the Network or Grid is set at 85 €/MWh for the Interconnected network and 95 €/MWh for Non-Interconnected Network (islands), using **all** fuels except natural gas. The Law introduces new, arbitrary, categorizations for HECHP units, far from the ones proposed by the EU Directives, 2004/8/EC and 2012/27/EC, and the Greek Law transposing the

2004/8/EC Directive into the Greek energy legislation. The HECHP systems are now divided into two distinctive categories, as:

a. Existing operating HECHP systems, and

b. New HECHP systems

More analytically:

a. For existing operating HECHP systems

The new categorization for existing HECHP systems are given in Table 13:

HECHP categories
HECHP, with NG, of ≤ to 1MW$_e$ for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of ≤ to 1 MW$_e$ for all remaining categories, according to the existing categories in 2004/8/EC
HECHP, with NG, of > 1 MW$_e$ up to ≤ 35 MW$_e$ for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of > 1 MW$_e$ up to ≤ 35 MW$_e$ for all remaining categories
HECHP, with NG, of > 35 MW$_e$ for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of > 35 MW$_e$ for all remaining categories

Table 13: HECHP categories for existing, operating systems

The new F-i-T pricing of high efficiency cogenerated electricity (in E/MWh) from operating units is based on two major types:

- HECHP investment without any subsides, and
- HECHP investment receiving subsidies, either from EU or national funds and are presented in Table 14.

HECHP categories	w/o subsides	w/ subsidies
HECHP, with NG, of ≤ 1 MW$_e$ for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	95+ANG	80+ANG
HECHP, with NG, of ≤ 1 MW$_e$ for all remaining categories	100+ANG	85+ANG
HECHP, with NG, of > 1 MW$_e$ up to ≤ 35 MW$_e$ for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	85+ANG	75+ANG
HECHP, with NG, of > 1 MW$_e$ up to ≤ 35 MW$_e$ for all remaining categories	90+ANG	80+ANG
HECHP, with NG, of > 35 MW$_e$ for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	62+ANG	57+ANG
HECHP, with NG, of > 35 MW$_e$ for all remaining categories	68+ANG	63+ANG

Table 14: F-i-Ts for different HECHP categories, with or without financial incentives

The term “ANG”, in Table 14, is referring to the adaptation of Natural Gas, a parameter that covers the variations of the cost of NG and is calculated with the following formula:

$$ANG=\left(\frac{(1-(\eta-\eta e))}{\eta hr}/\eta e\right) x \left(AMNGPt - 26\right) \quad (3)$$

where:

$\eta = \eta_e + \eta_h$: total efficiency of the HECHP unit

η_e = electrical efficiency of HECHP unit

η_{hr} = reference value for the separate heat production at HHV according to Table 15.

HECHP categories	Efficiencies
HECHP, with NG, of ≤ 1 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 33%, η_{hr}=81%
HECHP, with NG, of ≤ 1 MW_e for all remaining categories	η =67%, η_e= 33%, η_{hr}=81%
HECHP, with NG, of > 1 MW_e up to ≤ 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 1 MW_e up to ≤ 35 MW_e for all remaining categories	η =67%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 35 MW_e for all remaining categories	η =67%, η_e= 35%, η_{hr}=81%

Table 15: Reference value for the separate heat production for operating units

$AMNGP_t$ = average monthly mixed NG price (for HHV), including its selling price, its transport costs and the special duty tax to which is added the average CO_2 cost, corresponding to electricity production. The special duty tax is the addition of the $AMNG_m$ and $AMNG_\eta$, where $AMNG_m$ = the average monthly NG price (HHV) for cogeneration, in E/MWh, excluding the large electricity producers and this price is defined by YPEKA and $AMNG_\eta$ = the average monthly NG price (HHV) for NG users, in E/MWh, for customers on electricity production.

The average CO_2 cost is calculated by the following formula

$$\textbf{Ave } CO_2 \textbf{ (E/MWh) = 0.37 x ave. } CO_2 \textbf{ rights (E/tn) x } \eta_e \qquad \textbf{(4)}$$

The average CO_2 rights are obtained from the European Energy Exchange (EEX) in a monthly basis.

Regarding CHP units installed in agricultural sector or producing heat for DHS, L.4254/7.4.2014 gives to the fixed portion of "X+ANG" (excluding ANG) an extra 20%, which was further increased by 45% by an amendment in another energy Law, few months later, L.4273/11.7.2014.

b. For new HECHP systems, starting their operations after entry into force of L.4254/2014

There is a new categorization for newly operated HECHP units, substantially different from the previous presented in Table 16.

HECHP categories
HECHP, with NG, of ≤ to 1MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of ≤ to 1 MW_e for all remaining categories, according to the existing categories in 2004/8/EC
HECHP, with NG, of > 1 MW_e up to ≤ 5 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of > 1 MWe ≤ to 5 MW_e for all remaining categories, according to the existing categories in 2004/8/EC
HECHP, with NG, of > 5 MW_e up to ≤ 10 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of > 5 MW_e up to ≤ 10 MW_e for all remaining categories, according to the existing categories in 2004/8/EC
HECHP, with NG, of > 10 MW_e up to ≤ 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine
HECHP, with NG, of > 10 MW_e up to ≤ 35 MW_e for all remaining categories
HECHP, with NG, of > 35 MW_e for a) Combined cycle gas turbines with heat recovery

b) Condensate steam turbine	
HECHP, with NG, of > 35 MW_e for all remaining categories	
Remaining HECHP connected to the interconnected Network	
Remaining HECHP connected to the non-interconnected Network (islands)	

Table 16: HECHP categories for new HECHP systems

The new F-i-T pricing of high efficiency cogenerated electricity (in E/MWh) from newly operated HECHP units is based on two major types:

- HECHP investment without any subsides, and
- HECHP investment receiving subsidies, either from EU- or national funds and are presented in Table 17:

HECHP categories	w/o subsides €/MWh	w/ subsidies €/MWh
HECHP, with NG, of ≤ 1 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	88+ANG	76+ANG
HECHP, with NG, of ≤ 1 MW_e for all remaining categories	92+ANG	80+ANG
HECHP, with NG, of > 1 MW_e up to ≤ 5 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	80+ANG	70+ANG
HECHP, with NG, of > 1 MW_e up to ≤ 5 MW_e for all remaining categories	84+ANG	74+ANG
HECHP, with NG, of > 5 MW_e up to ≤ 10 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	74+ANG	65+ANG
HECHP, with NG, of > 5 MW_e up to ≤ 10 MW_e for all remaining categories	78+ANG	70+ANG
HECHP, with NG, of > 10 MW_e up to ≤ 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	68+ANG	62+ANG
HECHP, with NG, of > 10 MW_e up to ≤ 35 MW_e for all remaining categories	72+ANG	66+ANG
HECHP, with NG, of > 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	61+ANG	57+ANG
HECHP, with NG, of > 35 MW_e for all remaining categories	65+ANG	60+ANG
Remaining HECHP connected to the interconnected Network	85	80
Remaining HECHP connected to the non-interconnected Network (islands)	95	90

Table 17: F-i-Ts for different HECHP categories with or without financial support

The term “ANG” in Table 17 is referring to the adaptation of Natural Gas, a parameter that covers the variations of the cost of NG and is calculated with the following formula:

$$ANG=\left(\frac{1-(\eta-\eta e)}{\eta hr}/\eta e\right) x\left(AMNGPt-26\right) \quad (5)$$

where:

$\eta = \eta_e + \eta_h$: total efficiency of the HECHP unit

η_e = electrical efficiency of HECHP unit

η_{hr} = reference value for the separate heat production at HHV according to Table 18.

HECHP categories	Efficiencies

HECHP, with NG, of ≤ 1 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 33%, η_{hr}=81%
HECHP, with NG, of ≤ 1 MW_e for all remaining categories	η =67%, η_e= 33%, η_{hr}=81%
HECHP, with NG, of > 1 MW_e up to ≤ 5 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 1 MW_e up to ≤ 5 MW_e for all remaining categories	η =67%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 5 MW_e up to ≤ 10 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 5 MW_e up to ≤ 10 MW_e for all remaining categories	η =67%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 10 MW_e up to ≤ 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 10 MW_e up to ≤ 35 MW_e for all remaining categories	η =67%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 35 MW_e for a) Combined cycle gas turbines with heat recovery b) Condensate steam turbine	η =72%, η_e= 35%, η_{hr}=81%
HECHP, with NG, of > 35 MW_e for all remaining categories	η =67%, η_e= 35%, η_{hr}=81%

Table 18: Reference value for the separate heat production, for new units

$AMNGP_t$ = average monthly mixed NG price (for HHV), in €/MWh, including its selling price, its transport costs and the special duty tax to which is added the average CO_2 cost, corresponding to electricity production. The special duty tax is the addition of the $AMNG_m$ and $AMNG_\eta$, where $AMNG_m$ is the average monthly NG price (HHV) for cogeneration, in €/MWh, excluding the large electricity producers and this price is defined by YPEKA and $AMNG_\eta$ is the average monthly NG price (HHV), for NG users, in €/MWh, for customers on electricity production.
All above mentioned NG prices are issued by the corresponding Directorate of YPEKA and LAGIE is notified in a monthly basis.

The average CO_2 cost is calculated by the following formula

$$\textbf{Ave } CO_2 \textbf{ (E/MWh) = 0.37 x ave. } CO_2 \textbf{ rights (E/tn) x } \eta_e \quad (6)$$

The average CO_2 rights are obtained from the European Energy Exchange (EEX) in a monthly basis.

For both cases a. & b., the Law requires each cogenerator to register to Certification Bodies (i.e. NTUA, TUV, etc.) which are inspecting the installation and then they verify, at any operation time, the cogenerated electricity injected to the Network/Grid and reported to LAGIE. Only the cogenerators that installed the proposed instruments by Certification Bodies and followed the procedures, issued by LAGIE, with the assistance of HACHP, are eligible for incentives.

Regarding newly HECHP installations in agricultural sector or producing heat for DHS, the L.4254/2014 gives to the fixed portion of "X+ANG" (excluding ANG) is increased by 20% and 15% respectively.

Also, extra taxation and levies were imposed to the cogenerators, as:

- On 2010, taxation on all fuels, including NG, was imposed as a requirement of the 1st MoU between Greek government and lenders (EC-ECB, IMF).
- A 10% "special contribution" on the gross profit from the F-i-T monthly payment was imposed by the 2nd MoU between the lenders and the Greek Government, for 2+1 years, starting 6/2012 until 6/2015.

Another setback for the promotion of CHP, especially in the industrial sector, is that according to Article 143 of L. 4001/2011, the cogenerator auto-producers are obliged to pay two levies, as:

- «Special levy for reducing greenhouse gas emissions», which is paid by all electricity end-users (HV, MV, LV) according to their monthly consumption for paying off the emissions from coal-fired power plants, and
- “Utility Levy” which is referring to the compensation of PPC, as it provides a) Power supply for the residents of isolated islands, at the same prices as those of the inhabitants of the mainland, despite the fact that the cost of power production in the islands is much higher, b) Power supply at very low prices to families, with more than 3 children c) Power supply at low prices for vulnerable consumers such as the disabled, long-term unemployed, etc.

Regarding cogeneration units, using biomass or biogas as fuels, the F-i-T of cogenerated electricity, , are set by L. 4254/214, as: 85 €/MWh for the interconnected network and 95 €/MWh for Non-Interconnected Network (islands). So, investors using biomass/biogas are applying for the F-i-Ts for the “biomass/biogas” category, as RES, with the following tariffs, which are higher than those of CHP:

- 200 €/MWh with biomass installed capacity up to 1 MW_e
- 175 €/MWh with biomass installed capacity >1 MW_e and 5 MW_e.
- 150 €/MWh with biomass installed capacity >5 MW_e.
- 220 €/MWh with biogas installed capacity up to 3 MW_e.

The state support schemes were effective for a viable operation of a HECHP, until the introduction of new F-i-Ts by L.4254/2014. The current economic situation and the new feed-in-tariffs and the taxes imposed are creating a harsh environment to all cogeneration projects, resulting many of them to close down their operation. HACHP estimates that there is a decrease of 13-14% of the new F-i-T compared to the previous ones, after the implementation of the L.4254/14.

1.6. Barriers to CHP

The barriers for the promotion of cogeneration, in Greece, are categorized as **technical** barriers, **financial** barriers and **administrative**. Currently, a serious barrier, affecting CHP, is the economic recession and the weak Greek banking system, unable to finance high-capital investments, as CHP.

The past few years there have been efforts towards the penetration of CHP in Greek energy system, efforts in the legal framework (transposition of 2004/8/EC Directive, supporting schemes), awareness on the benefits of the technology on saving primary fuel, targets that Greece has to fulfil regarding EE. Nevertheless, there are still many parameters that function as barriers concerning the development of CHP at a national level. The barriers for the promotion of cogeneration are categorized as: **Technical** barriers (i.e. weather conditions, energy connections, etc.), **Financial** barriers (i.e. electricity/gas pricing, existing feed-in-tariffs, etc.) and **Administrative** barriers (i.e. legal issues, permit issues, etc.) and are presented below:

Barrier 1: Climatologic conditions of the country and the important role of cogenerated heat/cool

Greece is characterized by its Mediterranean climate, of mild winter and hot and dry summer. In different parts of Greece, a wide variety of climate is observed, due to the country’s topology, the variety of altitude and the alternation between land and sea. This explains the dry climate in the east part to the wet one in the north and west part of Greece. According to the observations and results from simulation from the World Weather Organization and the National Observatory of Athens, the winters in Greece are shortening in length but more intensive and with extreme temperatures. In many northern cities in Greece winter temperatures, are low, while, in late June and July, the maximum temperature, in many parts of Greece, reaches +35°C. Even before the economic recession, the energy intensive industries are constantly been reduced, while there is a small but constant growth of the so-called 'light' industries, as the food and beverage ones, which are requiring, except high electrical and thermal loads, high cooling loads, during the year (see food sector). In tertiary sector, there has been recorded an increase in the construction of different types of buildings, i.e. sports halls, malls, expo areas, etc, which are requesting, also, high amounts of electrical and heating/cooling loads, in order to create indoor thermal comfort conditions. RAE (Regulatory Authority for Energy) gave out the applications for cogeneration permits at 1.457,82 MW_e for the period 2009-2013[19] (1.074 MW_e for biomass). According to HACHP, all these are "on hold", due to the economic recession. As cogeneration should operate more than 3500 hrs per year, in order to become economically feasible, the operation a cogeneration unit used to cover only the heating loads, in Greece with the above mentioned climate, is not feasible and requires the introduction of appropriate cooling technologies, as absorption chillers, for covering the existing cooling loads. The tri-generation systems do not have the penetration expected in Greece, due to their high purchase and installation cost, the lack of knowledge of these systems by the technical world and the investors. So, the Greek state should create more concrete mechanisms to overpass their difficulties.

Barrier 2: Connection Procedures of micro - cogenerators into the Network

The access of cogenerated electricity to the Network is a rather complicated issue for cogenerators, in Greece, as no clear and well-defined regulations, from HTSO and PPC, exist, driving the cogenerators to negotiate with them, the terms of access from a minor position. More specifically, today in Greece, there is no define and concrete terms for connection of micro-CHP units to the Network, due to the lack of the agreement between cogenerators and the Administrator of Greek Electricity Distribution Network (AEDN) for the connection of the mCHP unit to the low-voltage network. Similar agreement between micro PV (up to 10 kW for roof-top PV applications) and AEDN exists. HACHP is in negotiation with AEDN to overpass this barrier.

Barrier 3: Fuel Pricing and Availability for CHP units

An important issue, regarding the further penetration of cogeneration into the Greek system, is the existing energy pricing policy, especially the low electricity pricing for both industrial, tertiary and household sectors and the high gas pricing, knowing the gas price connection to crude oil and its implications. According to many Greek cogenerators, both the electricity pricing by PPC and the gas pricing policy from 'high-pressure' providers (DEPA) and, also, 'low-pressure' ones (EPAs) is not adequate and appealing for the operation of cogeneration units of any type, creating major and serious problems for their viability. As a result of these tariff policies in gas and electricity is the discontinuation of many, mainly small-scale, cogeneration units, as they were creating negative financial conditions to the owners. An analysis of the energy prices is given in section 1.5 (*The economics of CHP*), showing the background of this barrier.

Barrier 4: Bureaucracy - Permit procedures for all types of CHP units

Although many positive steps have been made, bureaucracy still remains a very important barrier in Greece. Complicated legislation confuses investors, who often dispute on the interpretation of the law

[19] http://www.rae.gr/site/el_GR/system/docs/registry/ape_sithia.csp?viewMode=normal

with public services making the process even more time consuming. A two year period for all permits is considered as minimum. The procedures for obtaining the permit, for any CHP type, are considered as complicated and time consuming, by both cogenerators and consultants. For the completion of permits it is required the involvement of different public authorities (i.e. RAE, Ministry Energy Environment and Climate Change, local authorities i.e. Prefecture, etc). The most notable delay occurs during the procedures for the permit, titled ‘environmental assessment study’ by the local/regional authorities. According to the consultants, the average duration for obtaining this permit is more than 6 months. In 2013, the situation slightly improved, as YPEKA issued a well-defined roadmap for a CHP permit, for all players involved.

Barrier 5: CHP with RES (biomass) - lack of energy plant cultivation

Biomass is not yet a trade product, with a constant quality and price, in Greece. Also, the data of available quantities of any type of biomass is not considered as accurate, affecting CHP investments of this category, as they require continuity of primary energy resources and constant prices. Furthermore, there is a high logistics cost for biomass products, as a great majority of them comes from small or medium suppliers. The transportation cost to the CHP facilities is quite high, making sometimes uneconomic an investment of that kind. The need of energy plants supply, as part of raw materials using them as fuel, is also essential, as energy plants, due to their high heating value, are necessary. Unfortunately, their cultivation is not widespread, as it is not well known, among the rural world.

Barrier 6: Lack of awareness by technical world – Public

Lack of awareness among architects/civil engineers and consultants, who are playing important role in the design of new projects, especially buildings. The absence of technical knowledge works as a major barrier, as they are key actors for recommending the installation of a CHP system. Additionally, if a CHP system is recommended by the investor they devalue CHP, in order to hide their lack of knowledge to the technology. There is also lack of public awareness, as for the ordinary citizen, CHP is an almost unknown technology. Although most of them are aware of terms such as “energy efficiency” and “green energy” they still are not familiarized with CHP technology.

2. What is possible? Cogeneration potential and market opportunities

An economic potential of 1.455 MW_e and 2.299 MW_{th} of cogeneration for 2020 could be reached according to the “*Assessment of the National Potential for Combined Heat and Power in Greece, Ministry of Development 2008*” study. Notable penetration of CHP in tertiary sector and DH/DC systems.

Although the development of cogeneration in Greece is still quite limited, there are sectors where there appears to be an excellent potential for future growth.

The data presented below was obtained from a study, titled "*Assessment of the National Potential for Combined Heat and Power in Greece"*, and conducted by the Ministry of Development, in 2008. The following figures show the market (economic) potentials of cogeneration in Greece, until 2020. More analytically, Figure 4 shows the market potential of total production of electric energy by CHP, Figure 5 the market potential of total production of thermal energy by CHP and Figure 6 the market potential of both electric and thermal capacity produced by CHP.

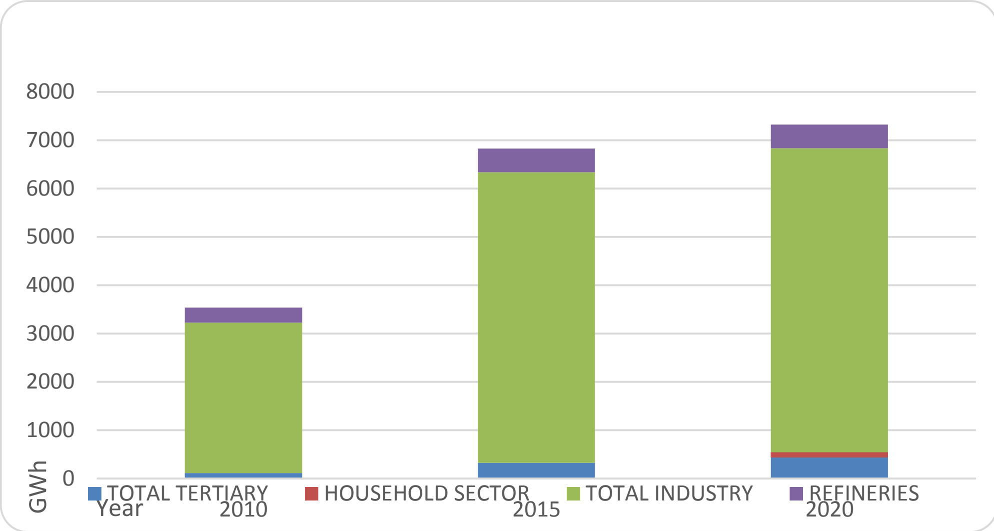


Figure 4: Market potential of total production of electric energy by CHP

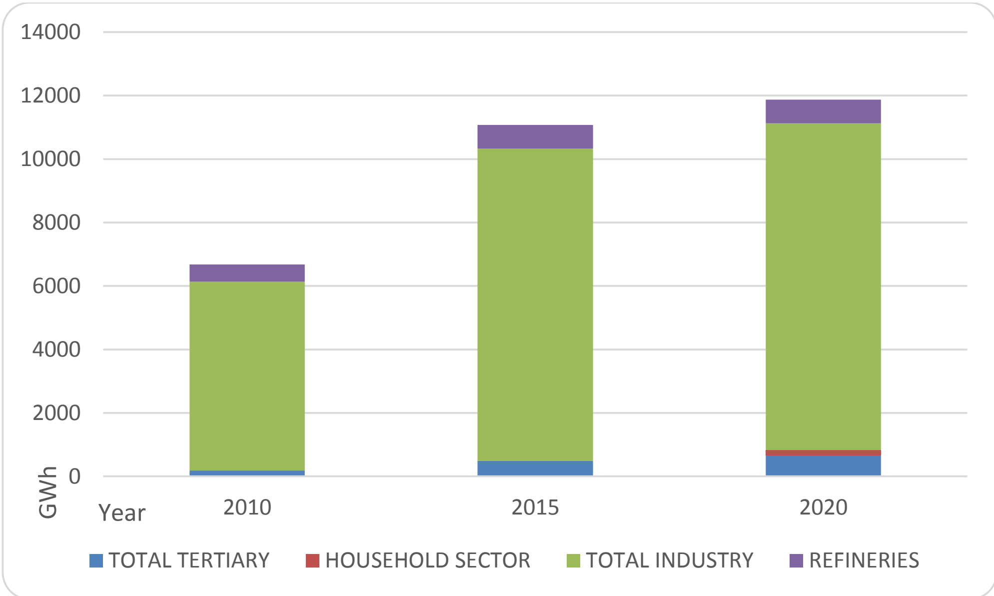


Figure 5: Market potential of total production of thermal energy by CHP

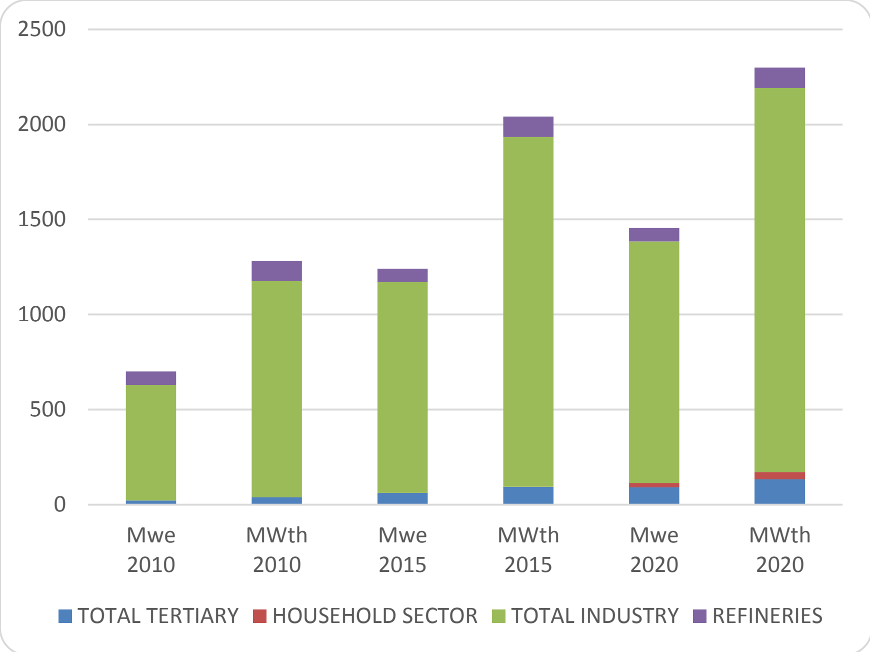


Figure 6: Market potential of Electric and Thermal capacity by CHP

It is clear from all three figures that the higher potentials, in absolute figures, lie in the industrial sector. The textile, food-beverages and non metallic minerals sectors are the ones showing the most intense future increase in cogeneration [20]. Especially, textile industries, holding a market potential capacity of 40 MW_e and $89MW_{th}$ by 2020, are developing again, after a sharp decline in 80s, and appear to hold a great opportunity for cogeneration expansion.

Tertiary and Residential sector

In the residential and building sector, an increase in cogeneration systems is foreseen, especially as the L.3851/2010 (Article 10) which requires that, by 31/12/2019 at the latest, all new buildings should meet all their needs for primary energy from energy supplying systems based on RES, cogeneration plants, district or block heating/cooling systems, as well as heat pumps. This Law creates new potential for trigeneration systems, set as an option according to TOTEE 20701-5/2012 (Technical Directive for CHP in buildings), concerning of high heating and cooling demands. This obligation shall apply to new buildings housing services of the public and wider public sector, by 31/12/2014.

Micro CHP

The potential in micro-CHP systems (see also Annex 3) is quite optimistic, due to the fact that according to the EED[21] these systems will be authorized to connect to the electricity grid and therefore be able to sell surplus electricity (see barrier No2). The penetration of micro-CHP is limited to areas where NG exists, therefore, the availiability of micro- and small-scale cogeneration systems is going to be directed towards to hotels, clinics, athletic centers and large residential apartments. There is an economic potential of cogeneration of 24 MW_e and $39MW_{th,}$ by 2020, in the residential sector according to the previously mentioned study *"Assessment of the National Potential for Combined Heat and Power in Greece".* (See annex 2)

Bio energy

[20] "Assessment of the National Potential for Combined Heat and Power in Greece" - Ministry of Development 2008.
[21] 2012/27/EU

Bio-CHP (see Annex 4) is alredy showing signs of further development. There is a projection of an increase of 30% in the biomass consumption by CHP from 2010 to 2020, given in the study "*Assessment of the National Potential for Combined Heat and Power in Greece".*

SMEs

Regarding SME's, there is also an increase, until 2020, as the study is showing. There have been EU structural fund programs, giving subsidies for energy upgrades especially in the tourist sector. Many SME's hold high heating, cooling and electricity demands. Cogeneration and trigeneration are technologies that could offer energy saving of their primary energy and lower their operational expenses. In addition to that, due to their relatively small size, their need for investment capital is not very big. Nevertheless, the current financial crisis struck the specific sector, resulting a great number of SME's to shut down.

In 2009, CRES composes the annual report concerning Energy Efficiency and RES, where it is strongly supported the dissemination and development of high efficiency cogeneration, by setting the 2015 and 2020 projections for cogeneration capacity.

According to these projections, the increase of cogeneration electricity, compared to 2010, will be 77% by 2015 and 107% by 2020. Also the predictions about cogeneration thermal capacity will be 59% for 2015 and 79% for 2020 (Table 19).

Development of electric and thermal capacity of CHP [22]						
	2010		**2015**		**2020**	
Area	**MW_e**	**MW_{th}**	**MW_e**	**MW_{th}**	**MW_e**	**MW_{th}**
Tertiary Sector	21	39	62	93	89	134
Residential Sector	0	0	0	0	24	39
Industry	609	1136	1111	1841	1271	2020
Refineries	70	107	70	107	70	107
Total	**700**	**1282**	**1243**	**2041**	**1454**	**2300**

Table 19: Development of Electric and thermal capacity of CHP

It should be added that in these projections were included the PPC's DHS in the industrial data.

It is true that, in 2008/9, the capacities for HECHP units granted permits by RAE were summed closed to these numbers, as new DHS were designed to be installed (i.e. Florina), but the economic crisis and the lack of financing by the Greek banking system completely stop these high capital investments.

[22] CRES annual report for 2009

3. How do we arrive there? : The Roadmap

3.1. Overcoming existing barriers and creating a framework for action

Key proposal is to adopt the obligations resulting from the EED as an opportunity for reviewing the current CHP policy, removing the existing barriers and revising the potential and opportunities of CHP further development. This is the challenge, as EED is not yet transposed into Greek legal system.

3.1.1. The obligations resulting from the EU-Energy Efficiency Directive should be taken as an impulse for reviewing the CHP policy.

The full transposition of EED into the Greek energy legal system is in its final stages, waiting the final approval by the parliament. EEF and especially Article 16's requirement to make cogenerated electricity equal to the RES one in terms of network access will provide easier connection to the cogenerators to the grid, with better financial terms. The best way to obtain this is by providing a 50% reduction in the connection cost for HE-CHP systems. The HTSO should provide, within a short period of time, binding connection reports. HECHP systems developed in the tertiary (small-scale CHP, up to 1 MW_e) and residential (micro CHP, up to 50 kW_e) sectors must be provided with a simpler, non-discriminatory access to the electricity grid. Simple rules should be established for micro-cogenerators to connect to the Grid and the rules provided by RAE should be clear and unambiguous. Additionally, HTSO personnel should be trained on these issues by experienced agencies. All that will make easier current procedures that they are lengthy and time-consuming.

Additionally, the EED requires that in the obligatory "*comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling*" according to Art. 14 a cost-benefit analysis shall be carried out based on socio-economic and ecologic criteria. Regarding the high capital intensity of CHP, it is also important that the discount rate used in the economic analysis for the calculation of net present values shall be chosen at a low value according to Annex IX of the EED and be nearby the discount rate as defined by the European Central Bank[23]. Generally the cost-benefit analysis should be based on a socio-economic consideration and not on common business level criteria (e.g. discount rate 2 to 3 % instead of > 10 %). This also will improve the penetration of tri-generation especially in hospitals, hotels, etc., lowering their current operation costs.

Finally, the existing limit-threshold of 35 MW_e in load allocation for priority, which is not based on any specific study or assessment analysis should be repealed. Greek government should follow the EED, which sets no capacity limits on the promotion of CHP and the transposition of the EED into the Greek legal system is a clear opportunity to address this issue.

3.1.3. The Government should consider revision of the new, changed recently, support scheme of F-i-Ts, eliminating bureaucracy, in order to make more appealing new CHP investments.

As mentioned earlier the L.4254/2014 introduces a new, arbitrary, categorization for HECHP units, far from the one proposed by the EU Directives, 2004/8/EC and 2012/27/EC. So, new limits were created, further to ones set by Directive 2004/8/EC, of 5, 10 and 35 MW_e. It is not clear the benefits from this

[23] Foot note 1 at part 1 of Annex IX EED: "The national discount rate chosen for the purpose of economic analysis should take into account data provided by the European Central Bank."

fragmentation, as nowhere in the world a CHP unit of 4 MW_e is treated differently than a one of 10 or 12 MW_e. It is clear that the State is not aware of the future advancement of CHP, their capacity and the sectors of application. This is based on the fact that there is no solid and coherent national energy strategy, which will highlights these cases. Noted that, under Article 11 of L.3734/2009, the Greek State should had already conducted a detailed study to detect the potential of CHP in Greece, but, until now, no detailed study on the necessary capacity exists. The L.4254/2014 does not promote growth for the industrial CHP and brings economic suffocation to the existing facilities, which will result in hundreds of unemployed workers in the field. HECHP units have multiple operating costs compared to RES, as they employ staff on a permanent and annual basis, especially those units working for agricultural sector or DHS. Specifically, they create on average of more than 15 permanent jobs per installed MW_e (versus to ~1 job position for RES). Also, it is not clear the distinction between all that different types of CHP technologies, explained in "*Economics of CHP*" section, if ultimately used for all almost similar efficiencies and fixed parts, the same cost per installed MWe, etc. Finally, the partial efficiencies correspond to systems with greater electrical efficiency than thermal, which can only be found in combined cycle plants. These efficiencies are in contrary to the European and Greek legislation referring to CHP. In Greece, HECHP presents many peculiarities and it is viable to the above mentioned «horizontal measures», which can be referred to completely different technologies and operational structures, like RES (mainly PV and wind). The CHP installations working as "main activity producers–independent producers", which barely reach the 100 MW_e in Greece, are still at early stage of maturity, starting to grow and they cannot be exposed to sudden and unnecessary changes in their supporting schemes, but, in contrary, they expect and require long-term stability.

Bureaucracy holds high level in policy barriers in Greece. Procedures should become shorter and simpler, which is already mentioned in EED 2012/27/EU. In addition, the reduction of authorization time plays, among others, an economic motive towards investors since they will be gaining profits from selling power earlier. Also, simpler support schemes shall provide a clear CBA for any investment. In article 15 of the EED the simplification and shortening of authorization procedures is suggested. Making authorization procedures simpler could increase the interest in CHP and provide a great incentive to candidate investors to complete the investment.

3.1.3. Implementation and operation of CHP by energy service companies (ESCOs) should be established and strengthened, following the implementation of EED

Energy service companies (ESCOs) can play a key role in mobilising additional CHP potentials, particularly in industry and commercial sector, in principle everywhere in the heating/cooling market. ESCOs use to calculate with longer payback times than industry. So, in many cases, ESCOs are able to bring the cogeneration potentials into reality, where otherwise "business as usual" would apply, meaning inefficient heat and steam production in boilers. As specialised experts on energy efficiency, ESCOs do have the necessary know-how on both technical and legal issues and they can offer solutions by "contracting" even as a part of an integrated efficiency package, including other energy saving measures regarding the supply of power, heat and cooling. CHP related energy services may be offered either by existing energy supply companies or by new suppliers. The implementation of Article 18 EED, requiring that "*Member States shall promote the energy services market* …" could be a core element for bringing the cogeneration potential of the industry into the reality. The same may apply for many other energy users e.g. in the commercial sector who are not able to invest and operate cogeneration units. It is important to make sure that cogeneration implementation by external ESCOs is explicitly supported, especially in its initial stages, as in Greece, taking into account that there is the legal framework, but not, still, a banking system suitable to finance these projects.

3.1.5. Government should boost development of a new support mechanism for cogenerators of up to 50 kW_e and for trigeneration.

Expanding the support schemes for the cogenerated electricity fed into the grid, from wider range of CHP systems, including now micro-scale CHP and for trigeneration units that now are not treated with attention. The capability of connection to the grid system of electricity produced from high-efficiency micro-cogeneration units, referred in the EED is moving towards this concept. So, a redesigning the subsidy systems is required and their expansion will give a significant economic incentive for investors to turn to micro-CHP and to trigeneration and/or district cooling systems, as EED requires.

3.1.6. A new awareness campaign of the benefits of HECHP targeting towards Government and energy market players should be boost in Greece-The important role of training, information campaigns, best cases, etc.

This is a combined effort to raise a new awareness campaign on the benefits of CHP, micro- and tri-cogeneration, through specialized seminars, published best cases studies that could provide more practical information to policy makers and experts from Government, to engineers and planners working for local and regional government, in order to promote this technology and to avoid setbacks as the last revision of the HECHP tariffs. Limited technical knowledge and know-how could be improved by a close cooperation between Greek government, ESCOs and educational institutes by bringing closer CHP experts and professionals who influence prospective investors.

Article 7 of the EED mentions training and education, including energy advisory programs, which lead to the application of energy- efficient technology or techniques and have the effect of reducing end-use energy consumption. An information campaign about all-types of HECHP and its advantages could raise public awareness and expand the options of enterprises and consultants.

3.2. Possible paths to growth

Three National Energy Strategy scenarios are introduced in "National Energy Planning Roadmap to 2050" composed by the Ministry of Environment, Energy and Climate Change. The implementations of the measures described in the scenarios are estimated to be completed by 2020; therefore the quantitative differentiations are calculated from 2030 to 2050.

The "*National Energy Planning Roadmap to 2050*" composed by the Ministry of Environment, Energy and Climate Change in Greece, introduces three scenarios concerning the national energy development: the "*Existing Policies*" scenario (EP), the "*RES Maximization Measures*" scenario (RMM) and the "*Environmental Measures of Minimum Cost*" scenario (EMMC)[24]. The main characteristics of each scenario are:

a) "**Existing Policies-EP**" scenario:

- Conservative implementation on energy and environment policies.

[24] "National Energy Planning, Roadmap to 2050", Ministry of Environment, Energy and Climate Change, March 2012.

- Moderate level of reducing greenhouse gas emissions by 2050, by at least 40% compared to 2005.

- Provide modest penetration of RES and Energy Efficiency technologies, such as cogeneration as a result of conservative political implementation.

The results of the EP scenario would be:

- Containment of the average annual investment costs for electricity production and lower total cumulative investment cost of electricity production, by 2050.

- Maintain participation of indigenous fossil fuels for electricity generation.

- Capacity utilization of electricity generation from RES.

b) “**RES Maximization Measures-MM**” scenario:

- Maximization of RES penetration in electricity generation reaching the level of 100%.

- Reducing greenhouse gas emissions, by 60%, by 2050.

- High energy efficiency in buildings and transport.

- Further penetration of cogeneration systems in industries.

- Increase of cogeneration installations in households and SME’s.

- Development of DH and DC systems.

The results of the RMM scenario would be:

- Achievement of environmental objectives with optimal electricity generation technologies (minimum costs solution for the national economy).

- Reduction of energy dependence and greater protection from fluctuations in fossil fuel prices and geopolitical unrests.

- Optimum utilization of domestic capacity in renewable energy without significant high needs for storing electricity.

- Low requirements for use of new technologies for electricity generation and storage.

- High contribution shares of RES in gross final energy consumption in total and per sector (electricity, heating and cooling, and transport).

- Slight increase in the average investment cost for electricity generation and smart grid development.

- Enhancement of competitiveness and creation of new job positions.

c) “**Environmental Measures of Minimum Cost-EMMC**” scenario:

- RES penetration in electricity generation, reaching the level of 85%.
- Reducing greenhouse gas emissions, by 60%, by 2050.
- High energy efficiency in buildings and transport.
- Construction of great number of cogeneration plants using biomass, biogas and NG as fuels.
- Further penetration of cogeneration systems in industries.
- Increase of cogeneration installations in households and SME's.
- Development of DH and DC.
- Development of trigeneration systems.

The results of the EMMC scenario would be:

- Independence from imports and de-carbonization of electricity generation to the maximum extent.
- High participation of RES in gross final energy consumption.
- Significant penetration of electricity and biofuels in the transport sector.
- Domestic industry development of RES technologies and high energy efficiency systems such as cogeneration due to high demanding.
- Possibilities for exchange or export of energy from RES.
- Enhancement of competitiveness and creation of new job positions.

The perspective of the above scenarios is for 2050, while the implementation of the needed measures will be completed by 2020. Therefore, quantitative differentiation of the scenarios is calculated for 2030 and afterwards. Figures 7 and 8 are shown the Potentials of Electric and Thermal capacity of cogeneration in Greece for each of the three scenarios (a: EP, b: RMM, c: EMMC) by 2030.

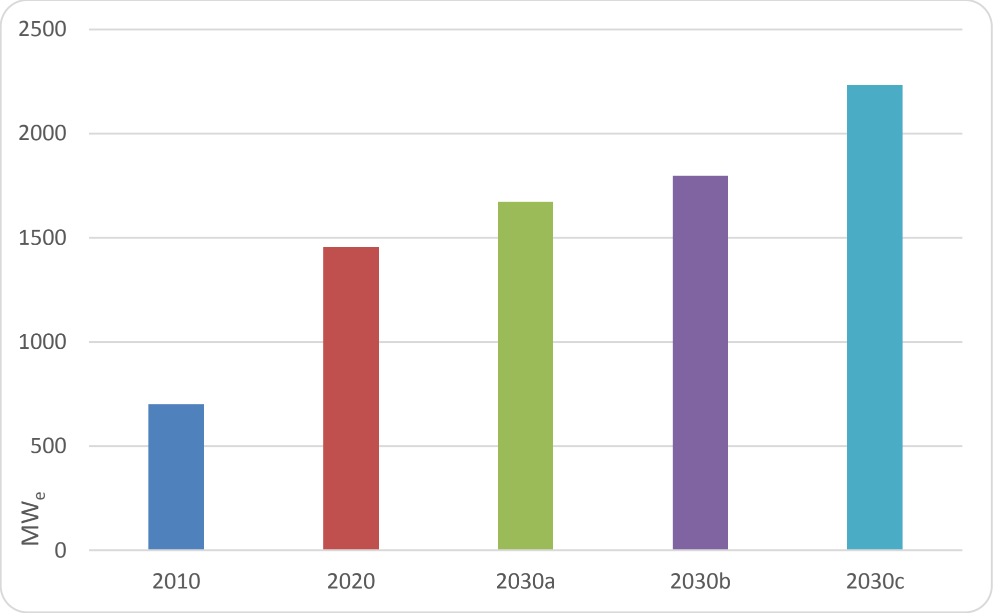


Figure 7: Potential of the electricity capacity of CHP for each of the three scenarios, by 2030[25]

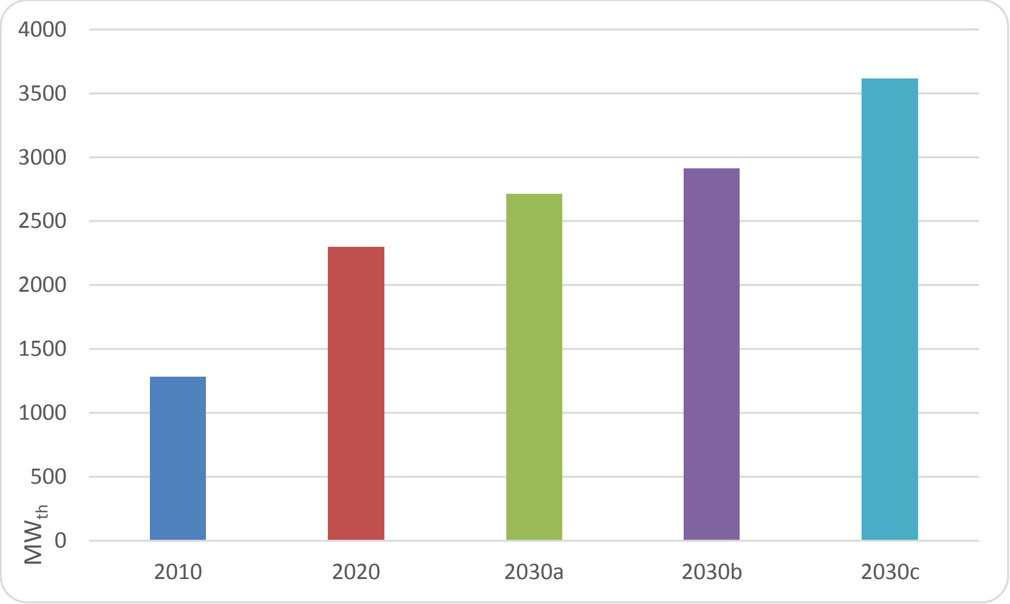


Figure 8: Potential of thermal capacity of CHP for each of the three scenarios by 2030[26]

3.3. Saving of primary energy and CO_2 emissions by the CHP roadmap

Primary energy saving (PES) and CO_2 emissions saving projections resulting from increased use of CHP require assumptions about not just what types of fuel and technology are displaced, but also their operation on the market. Within CODE2 two approaches are developed. These represent two different analytic considerations, which are summarised here and more fully explored in Annex 5.

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[25] "EU energy trends to 2030 — UPDATE 2009", EUROPEAN COMMISSION Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG

[26] "EU energy trends to 2030 — UPDATE 2009", EUROPEAN COMMISSION Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG.

1) **Methodology according to Annexe s I and II of the EED**. This method is used at a member state level today for national reporting to the European Commission and at project level for determining if a specific CHP plant is highly efficient. In the methodology, the efficiency of each cogeneration unit is derived by comparing its actual operating performance data with the best available technology for separate production of heat and electricity on the same fuel in the market in the year of construction of the cogeneration unit using harmonized reference values which are determined by fuel type and year of construction.

2) **Substitution method**. This method has been developed within the project and estimates the amounts of electricity, heat and fuel which are actually replaced by additional new CHP based on a projection of the supply base changes in the member state supply over the period are calculated. The situation in 2030 is compared to the current status. With this method PES for Greece through implementing the roadmap for CHP is estimated at a 20 TWh per year and CO_2 savings are estimated to be 12 million tons per year until to 2030. The actual saving is particularly dependent on the efficiency increase through upgrading both current power plant and CHP technology efficiencies. The final share of bio energy in additional CHP has a major impact on the CO_2 savings, which can be anticipated. The CO_2 reduction achieved is due to both higher energy efficiency and fuel switching towards low carbon (natural gas) or non-carbon (bio energy) fuel, but CHP development and fuel switching are anticipated to be an integrated process driven by policy objectives.

	Substitution method		**EED method**	
	Low case	**High case**	**Low case**	**High case**
PE saving	24.35 TWh/a	24.8TWh/a	11.1 TWh/a	11.1 TWh/a
CO_2 saving	14 Mio t/a	14.7 Mio t/a		
- per kWh el*	1.18 kg/kWh el	1.47 kg/kWh el		

Table 20: Saving of primary energy and CO_2 by the Greek CHP roadmap

* This value represents the CO_2 reduction of the power generation. It includes the avoided CO_2 emissions from fuel savings for separate heat generation in boilers; it must not be confused with the considerably lower CO_2 emissions of the substituted condensation electricity or with even lower emissions of compared power production according to the BAT approach in accordance with the EU CHP directive reference values.

ANNEXES

1. Stakeholder group awareness assessment

A questionnaire on awareness of CHP and its benefits in the main groups was distributed to Greek experts in meetings at Energy Conferences where CODE2 programme was presented.
They were asked to fill a table with the main user groups and to give back their personal opinion on the grade of awareness. The results can be seen in Table A.1.

Table A.1: Ratings of CHP awareness of different influential groupings

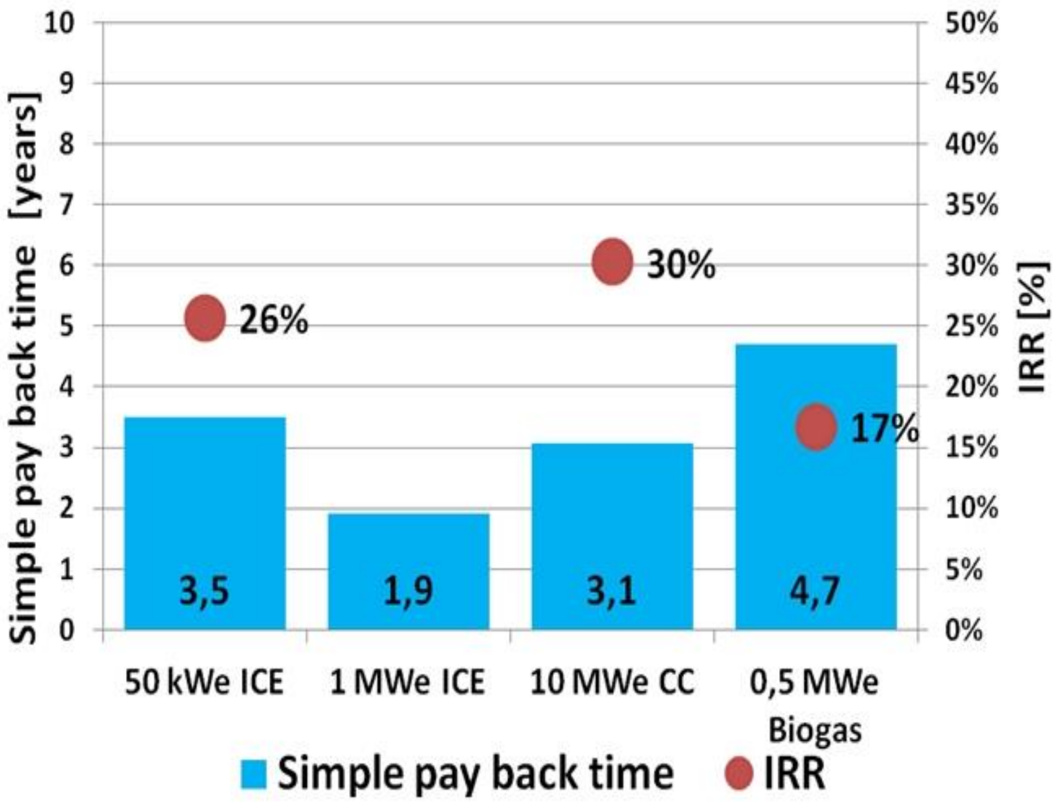
Customers	
Utilities	Cogeneration is commonly known in the utilities sector.
SMEs	Cogeneration is quite known in some of these groups. Nevertheless there are only a few examples of completed cogeneration system installations up to 1 MW_e. Due to lack of own funds, subsidies are often necessary for such investments to be made. Small family-run companies or individuals are not well informed and with limited cash flow and without any loans from the banks they don't invest to any energy efficiency technologies.
Households	For the ordinary citizen, cogeneration is an almost unknown technology. Although most of them are aware of terms such as "energy efficiency" and "green energy" they still are not familiarized with cogeneration technology. Small and micro-CHP systems are good means to raise awareness of the efficiency of a cogeneration approach, since these systems could interest individuals, who with a relatively low cost would like to improve the energy efficiency of their houses.
Industry	Cogeneration is well known in principle. Due to today's financial crisis in Greece, most of the businessmen hesitate to invest even knowing cogeneration's benefit.
Market and supply chain	
Manufacturers	There is not a strong presence of cogeneration manufacturers in Greece. Although manufactures hold a high level of awareness, most of cogeneration systems are promoted and distributed by local resellers.
Installers	Cogeneration is known in principle and detailed know-how is at a good level. Unfortunately, due to the low level of interest among user groups there are only a few installation companies in Greece.
Grid operators	Cogeneration is known in principle and detailed know-how is at a good level.
Consultants	Cogeneration is known in principle, but often the detailed know-how design is missing.
Architects	Cogeneration solutions are mostly known only superficially. The focus is on solar thermal, heat pumps and pellets. HACHP in an effort to increase awareness on CHP made several contacts to engineering offices to promote cogeneration. Also a Technical Directive titled "Installation of micro and small cogeneration in Buildings", issued by Technical Chamber of Greece, can be a useful guide to all engineers, working on buildings. There, also, could be more informative activities towards construction companies and engineers.

Banks, leasing	There are major problems for cogeneration financing. Although a few years ago financing of CHP systems was secured, nowadays due to the economic crisis, this is minimized.
ESCO's	Cogeneration is known in principle and detailed know-how is at a good level.

Influencers	
Information of the broader public	For the ordinary citizen, cogeneration is an almost unknown technology. Although most of them are aware of terms such as "energy efficiency" and "green energy" they still are not familiarized with cogeneration technology. There are exceptions of well-informed individuals, where many of them have already or are thinking about investing in micro-CHP systems. Small and micro-CHP systems are good means to raise awareness of the efficiency of a cogeneration approach since these systems could interest individuals, who with a relatively low cost would like to improve the energy efficiency of their houses.
Specialist Media	Cogeneration technology is quite known among the specialized on energy media. Media generally hold a good image about CHP, which is considered, decentralized, environmentally friendly and close to the citizen. The daily papers and TV programs mention cogeneration infrequently. The problem could be that specific technology terms are difficult to process for ordinary journalists and there is a low level of interest by the general public.
Universities/ Colleges	Only some of the polytechnic schools and universities and technical colleges deal with cogeneration either in research or including cogeneration in their syllabus.
Research	There is research in some polytechnic schools and universities dealing with cogeneration. There is a good knowledge only in a few institutes.
NGOs	Good image: decentralized, environmentally friendly, citizen close.
Planners	Cogeneration is known in principle, but often-detailed know-how is missing.
Energy agencies	Cogeneration is well known, but there have been little steps in disseminating this awareness among interest groups.

Policy	
Policy development at different levels:	The Government has fulfilled all required by EU Directives regarding CHP. But it does not consider CHP as an energy efficient technology that requires steady environment to grow. This is mainly due to the lack of knowledge of the benefits of the technology, by state officials. Nevertheless, there have been few progress steps concerning CHP.

2. Micro CHP potential assessment



micro-CHP potential summary Greece

Country statistics

Population: 11 300 000 (2010)
Number of households: 4 350 000 (2010)
GDP per capita: € 20 100 (2010)
Primary energy use: 19 000 ktoe/year (2010)
GHG-emissions: 118 Mton $CO_{2,eq}$/year (2010)

Household systems (±1 kWe)

Boiler replacement technology

Present market (2013)
Boiler stock: 1 000 000 units
Boiler sales: 47 000 units/year

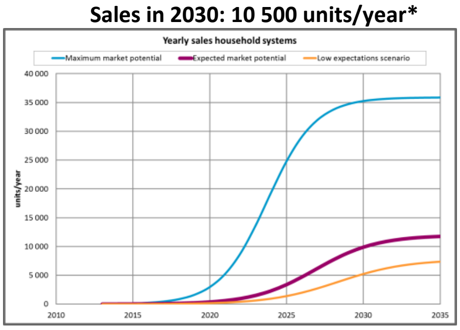
Potential estimation

Indicator	*Score*
Market alternatives	2
Global CBA	0
Legislation/support	2
Awareness	1
Purchasing power	1
Total	**4 out of 12**

Expected final market share: 26% of boiler sales in Household sector

Yearly sales

Sales in 2020: 380 units/year*
Sales in 2030: 10 500 units/year*



Stock

Stock in 2020: 1 000 units*
Stock in 2030: 46 000 units*
Stock in 2040: 117 000 units*

Potential savings in 2030

Primary energy savings:
1 PJ/year*
21 ktoe/year*
GHG-emissions reduction:
0.2 Mton $CO_{2,eq}$/year*

SME & Collective systems (±40 kWe)

Boiler add-on technology

Present market (2013)
Boiler stock: 1 030 000 units
Boiler sales: 48 000 units/year

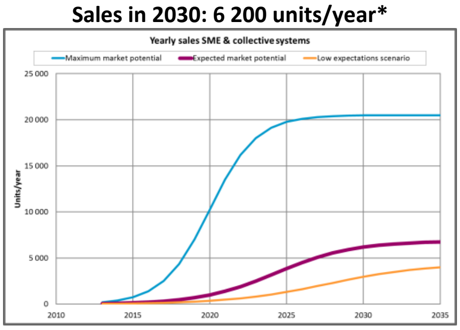
Potential estimation

Indicator	*Score*
Market alternatives	2
Global CBA	0
Legislation/support	2
Awareness	1
Total	**3 out of 9**

Expected final market share: 14% of boiler sales in SME & Coll. sector

Yearly sales

Sales in 2020: 1 000 units/year*
Sales in 2030: 6 200 units/year*



Stock

Stock in 2020: 6 000 units*
Stock in 2030: 41 000 units*
Stock in 2040: 68 000 units*

Potential savings in 2030

Primary energy savings:
11 PJ/year*
271 ktoe/year*
GHG-emissions reduction:
2.1 Mton $CO_{2,eq}$/year*

*Corresponding to the expected potential scenario.

micro-CHP score card
Argumentation

The score card is used to assess the relative position of an EU country based on current regulations, markets and economics. The score itself functions as input to the implementation model to 2030.

±1 kWe systems (Households)
Boiler replacement technology

Scorecard

Indicator	Score
Market alternatives	2
Global CBA	0
Legislation/support	2
Awareness	1
Purchasing power	1
Total	**4 out of 12**

Market alternatives

The NG grid is well developed in many major cities, there is a plan for further development.

Global CBA

SPOT: ***not economical***

Legislation/support

Current incentives

For the time being no possibility to sell to the grid the surplus electricity for ±1 kWe systems (Households).

L.3851/2010 (Article 10) requires that, by 31/12/2019 at the latest, all new buildings should meet all their needs for primary energy from energy supplying systems based on RES, CHP plants, district or block heating/cooling systems, as well as heat pumps.

Current legislation in favour

L.4001/2011, transposes, into national legislation, the third Internal Energy Market Directive. Among others, it stipulates the unbundling of the system operators and enhances the role of the independent regulator, regarding security of supply, licensing, monitoring of the market and consumer protection, cancelling the 35 MWe barrier, as the upper limit installed capacity for a CHP unit to be characterized as "High Efficient" one.

Awareness

Are stakeholders aware of the microCHP technologies

Homeowners? ***For the ordinary citizen, CHP is an almost unknown technology***

Consultants? ***CHP is known in principle, but often the detailed know-how design is missing.***

Installers? ***CHP is known in principle and detailed know-how is at a good level.***

Planners? ***CHP is known in principle, but often the detailed***

±40 kWe systems (SME & Collective systems)
Boiler add-on technology

Scorecard

Indicator	Score
Market alternatives	2
Global CBA	0
Legislation/support	2
Awareness	1
Total	**3 out of 9**

Market alternatives

The NG grid is well developed in many major cities, there is a plan for further development.

Global CBA

SPOT: ***not economical***

Legislation/support

Current incentives on microCHP

L.3851/2010 (Article 10) requires that, by 31/12/2019 at the latest, all new buildings should meet all their needs for primary energy from energy supplying systems based on RES, CHP plants, district or block heating/cooling systems, as well as heat pumps *Current legislation in favour*

L.4001/2011, transposes, into national legislation, the third Internal Energy Market Directive.

Awareness

Are stakeholders aware of the microCHP technologies

Consultants? ***CHP is known in principle, but often the detailed know-how design is missing.***

Installers? ***CHP is known in principle and detailed know-how is at a good level.***

Planners? ***CHP is known in principle, but often the detailed know-how design is missing.***

know-how design is missing.

Government? ***CHP is known in principle.***

Are manufacturers active in the market? ***Only through resellers. There are no manufacturing companies in Cyprus.***

Purchasing power	
GDP: ***€ 20 100 per year***	

3. Bio CHP potential assessment

Approach for bio-CHP potential analysis

EU Potential for bio-energy CHP

The goal of this analysis is to estimate the uptake and thus the implementation potential, not the theoretical maximum potential, for bio-energy CHP in the 27 EU-member states (MS) until 2030.
To this end, the following main sources have been used to arrive at country specific potentials:

1. Data on "Heat demand from CHP and DH" from the EU energy trends to 2030[27] (based on PRIMES database)[28]
2. Data of targets for "biomass for heating" from the National Renewable Energy Action Plans of the MS[29]
3. Current levels of biofuel inputs to CHP from EAA/Eurostat[30]
4. Biomass potentials from the "Atlas of EU biomass potentials" (Project Biomass Futures)[31]

The approach chosen to perform this bio-energy CHP potential analysis and the basic assumptions are as follows:

Scope and assumptions, analysis steps

The theoretical potential for bio-energy CHP is seen as the 100% fuel switch to bio-fuels in the CHP systems of a given country – in district heating (DH) as well as in industry. The aim of this study is to project on MS level the heat demand from bio-energy CHP systems – also in relation to the heat demand from all CHP systems – in 2030 with a milestone 2020.

Step 1: Heat demand from CHP and DH

The main data source for the development of CHP in the MS are the figures for *heat demand from CHP and DH* (Source: PRIMES) as published in the EU Energy Trends to 2030, Reference Scenario[32] (blue curve in country reports). In countries, for which specific energy trend data for CHP were available (e.g. Germany), these were chosen instead of the PRIMES data.

Step 2: Current and future bio-energy penetration rate

Coming from the current level of bio-energy CHP utilisation (EEA/Eurostat; 2010 value of green curve in country reports), the assumption is that the markets for bio-energy CHP will develop in close relation with the targets of the Renewable Energy Directive and the projections for renewable energy utilization as stipulated in the EU Energy Roadmap (30% in 2030). These figures are then further adapted on country level using specific national sources and in contact with national experts to arrive at a development path for the heat demand from bio-CHP for each MS (2030 value of green curve in country reports).

Step 3: Determination of growth curve

To determine the curve shape for the development of bio-CHP (green curve in country reports), two sets of data are used as reference (normally weighed 50:50): Firstly, the national target figures *Biomass for heating* (2015 and 2020, own extrapolation for 2025 and 2030) as laid down in the member states'

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27 European Commission, DG Energy: "EU energy trends to 2030"; 2009.

28 In some MS additional data or projections have been identified for "Heat demand from CHP and DH" or "bio-fuel input in CHP" and have been used instead of the sources mentioned here. Wherever this was done, the respective sources are mentioned in the respective country report.

29 Energy Research Centre of the Netherlands, European Environment Agency: "Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States"; 2011.; no figures available for Romania

30 European Environmental Bureau, Eurostat: "Fuel input to CHP plants in EU-27 and EEA countries in 2009", http://www.eea.europa.eu/data-and-maps/figures/fuel-input-to-chp-plants-4

31 Alterra, IIASA: „Atlas of EU biomass potentials: Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources", 2012.

32 Reduced by the share of non-CHP heat according to IEA and EUROSTAT statistics.

National Renewable Energy Action Plans (yellow curve in country reports). Secondly, the development of the *final heat demand from CHP & DH* as projected by PRIMES (blue curve in country reports). Using IEA figures[33], the non-CHP parts of DH in the PRIMES figures has been eliminated.

The intermediate result is a *projected heat demand from bio-energy CHP* under favourable framework conditions (green curve in country reports).

Step 4: Assessment of framework conditions through scorecard

In a further step, the bio-energy CHP penetration curve is modified by assessing the national frameworks for biomass fuelled cogeneration with a score card[13]. In this scorecard, the following aspects have been assessed and weighed:

- Legislative environment
- Suitability of heat market for switch to bio-energy CHP
- Share of Citizens served by DH
- National supply chain for biomass for energy
- Awareness for DH and CHP

Applying the scorecard results then results in the projection of the bio-energy heat demand from CHP and DH (in ktoe) for 2020 and 2030 (red curve in country reports).

Step 5: Assessing biomass availability

To cross-check, whether the projected demand can be satisfied with cost-efficient biomass available within the MS, the demand figures are compared with national biomass availability figures as published by the project "Biomass Futures" in the Atlas of EU biomass potentials (2012)[34] (pink curve in country reports). Due to the ongoing discussion in the EU about sustainability criteria for bio-energy, the figures from the Atlas' sustainability scenario were chosen, which take into account not only existing legislation but assume stricter sustainability rules to be applied in the future also for solid and gaseous biomass. As the Biomass Futures project also investigated price-levels, the figures used here describe a rather conservative assumption of biomass availability per country. It is assumed, that the technology to use the different sorts of cost-efficient biomass resources (largest groups: straw, manure, perennial cropping, forestry residues, waste) for CHP purposes will be available.

Areas not covered

Although being important factors for the future development of bio-energy CHP markets, due to limited availability of data the following aspects have not been incorporated in the potential this analysis:

- Small-scale CHP
- Trigeneration
- Regional or local biomass availability
- Biomass imports

Bio-energy CHP potential in EU-27

25 member states[35] have been assessed with the approach described and are summarised each in a 2 page country report. These reports will be subject to further discussions on MS level in the context of the CHP road maps which are presently under development.

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[33]: Website International Energy Agency, Statistics section: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat Score ratings by member state CHP experts.

[34] Assumptions for arriving at the available biomass for bioenergy CHP: 65% of available biomass used for heating; CHP factor 0.8.

[35] France: still in discussion with experts; Malta: insufficient data, no (foreseeable) relevance for CHP

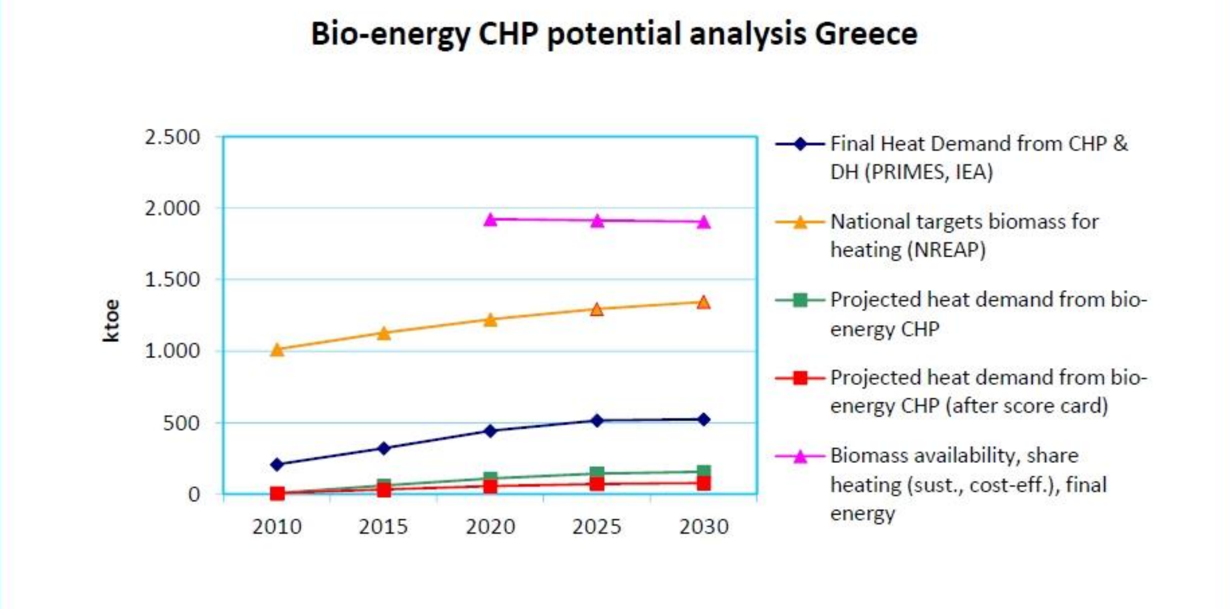
For the European Union, an overall assessment was established by aggregating the individual country figures. As country specific frameworks and policies are important aspects, which were assessed through the scorecards, this section is not depicted in the EU summary.
Analysing the overall picture from the member state level bio-energy CHP potential analyses, the following trends and conclusions can be made:

- There will be a steady increase in CHP heat demand in the EU until 2030
- *The strong increase in biomass for heating as stipulated in the MS's NREAPs will also* support the development of bio-energy CHP
- The expected penetration rate of bio-energy CHP in CHP markets is expected to reach 27,1% in 2030 (up from 19,5% in 2009)[36]
- The framework conditions – politically, economically, regarding awareness – for (bioenergy) CHP vary greatly throughout EU
- Under optimum framework conditions on national level, the penetration rate could reach 33% in 2030
- For the projected development, sufficient cost-efficient and sustainably produced biomass resources are available on a national level for further growth of bio-energy CHP. Again, the situation varies greatly between member states. In densely populated countries the nationally available biomass resources may fall short of the demand.
- To maximise the potential, technological progress towards the use of the whole range of biomass fuels should be promoted

[36] The three countries Germany (large CHP market by volume), Sweden and Finland (both good CHP markets with high biofuel share) account for 76% of the bio-CHP heat demand in EU-27 (2009).

Bio-energy CHP potential analysis Greece

Figures (projections)	2010	2020	2030
Final heat demand from CHP and DH (PRIMES, IEA), ktoe	207	442	524
(Projected) heat demand from bio-energy CHP and DH (after score card), ktoe	7	55	77
Bio-energy penetration rate in CHP markets (2009: EEA, Eurostat)	3,4% (2009)	12,5%	14,7%
Biomass availability, share heating (sust., cost-eff.), final energy (Biom. Futures), ktoe		1.922	1.906



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Framework Assessment (Score card)	Score	Short analysis
Legislative environment	+ 2 (of 3)	New Development Law with incentives on Energy Efficiency, including DH – There are private DH network in operation in GR, with good results
Suitability of heat market for switch to bio-energy CHP	- 0 (of 3)	Not yet an industrial attempt for bio-energy in industry
Share of Citizens served by DH	o 1 (of 3)	There is one DH system in GR with a partial biomass boiler, but the operating results are not known yet
National supply chain for biomass for energy	+ 2 (of 3)	New area with good potential
Awareness for DH and CHP	+ 2 (of 3)	There is an awareness for HECHP and DH, as well as for bio-energy

Comments on country analysis

General comments

- The national framework assessment through the scorecard results in an average score (7 of 15 possible points).
- Thus, it is projected that the growth potential for bio-CHP until 2030 will be exploited to 47%.
- The possible bio-CHP penetration rate in 2030 (2030 dot of green curve) under ideal framework conditions is seen at 30% (the country's RE target according to RED (28/2009) is at 18% in 2020)
- The share of bio-fuels in CHP (bio-energy penetration rate in CHP markets) is expected to rise from 3,4% (2009) to 14,7% (2030)
- The national biomass availability (cost-efficient, sustainable; pink curve) is sufficient to enable the projected growth; however, these biomass resources include types of biomass which are currently not usually used in CHP, but are expected to be utilizable by 2030

Specific issues

- The projected development of CHP heat demand (PRIMES, blue curve) foresees constant growth especially between 2010 and 2020
- National targets for biomass for heating (yellow curve) also see a constant growth
- The growth projections of the bio-energy CHP heat demand (green and red curves) apply the average growth rates of both the blue and the yellow curve (weighting 50:50)

4. Assumptions used in the market extrapolation

Detailed economic analysis of four CHP cases was implemented in all pilot roadmaps and optionally in non-pilot ones.

As requested detailed economic data analysis of the four CHP cases were not available or are not sufficiently reliable for making objective conclusions about CHP profitability and comparison of economics with other member states, detailed calculations is not included in this report.

5. *Example profitability calculations*

Sector		Heating in services and multifamily houses	Industry and service process heat and heating supply	Industrial process heat and district heating
		50 kWe ICE	1 MWe ICE	10 MWe GT
Technology		**ICE**	**ICE**	**GT**
Power	**MW_{El}**	**0,05**	**1**	**10**
Efficiency-el.	Eff_{EL}	34%	42%	35%
Efficiency-th.	Eff_{H}	56%	41%	45%
Efficiency-sum.	Eff_{SUM}	90%	83%	80%
Operation	**h/a**	**4.000**	**5.500**	**7.500**
Fuel	MWh	588	13.095	214.286
Electricity	MWh	200	5.500	75.000
Heat	MWh	329	5.369	96.429
Investment	**EUR**	**115.000**	**1.100.000**	**11.500.000**
	€/kWel	2.300	1.100	1.150
O&M costs	% of Inv.	1,5%	1,5%	1,5%
Price of fuel	€/MWh	68	63	49
Value of electricity	€/MWh	106	100	100
Value of heat	€/MWh	80	75	70
Support				
Electricity	€/MWh_{El}	115	115	Auto-producer
Other	€/a			
Investment subsidy	€			
Costs & revenues				
Fuel	€/a	-40.000	-825.000	-10.405.714
Electricity	€/a	21.200	550.000	7.500.000
Heat	€/a	26.353	402.679	6.750.000
Support	€/a	23.000	632.500	0
Maintenance	€/a	-1.725	-16.500	-172.500
TOTAL	**€/a**	**28.828**	**743.679**	**3.671.786**
SPB	**years**	**4,0**	**1,5**	**3,1**
IRR	**%**	**21%**	**67%**	**30%**

6. Methodologies used to calculate the saving of primary energy and CO_2 emissions under the roadmap.

Substitution method

This method has been developed in the CODE2 project. In doing this, two other approaches have been considered: 1) the "replacement mix method[37]" from the Munich FfE institute, which however cannot be used directly for a long term comparison as needed in CODE2; 2) a method used to calculate the CO_2 saving resulting from a voluntary commitment of the German industry for CO_2 reduction[38], however this method has been considered as too simple. Therefor the following more differentiated approach has been developed:

Based on an estimate of the increase in cogeneration electricity the thereby caused decrease of CO_2 emissions and primary energy consumption is estimated. In this approach, an attempt is made to determine the actual quantities saved compared to the base year (e.g. 2010). Hence it refers to the actual saving of fuels for the production of the amounts substituted by modern CHP plants

a) of electricity and heat in the replaced or retrofitted old CHP plants

b) of electricity in power plants

c) of heat in boilers.

The savings result from a combination of three effects:

- CHP effect

- Technology effect (improved CHP technologies)

- Fuel switching (e.g. lower carbon content of natural gas compared to coal, CO_2 neutrality of bioenergy)

The results show the savings actually induced by the expansion of CHP compared to the situation in the base year.

This approach differs fundamentally from the methods for checking the high-efficiency according to the CHP Directive or in accordance with ANNEX II of the EED (Directive 2012/27/EU on energy efficiency), in which a comparison between CHP and the best available Technology (BAT) of separate production of electricity and heat produced is carried out strictly on a same-fuel basis.

This procedure is considered to be inappropriate to deliver an estimate of the actual fuel saving quantities by CHP over a longer period, which is considered relevant value, representing meaningful the contribution of CHP to the long-term objectives of the EU to reduce CO_2 emissions and primary energy consumption. The BAT approach of the CHP Directive has been developed to verify the high efficiency of individual plants, but not to determine actual saved CO_2 emissions and primary energy quantities by CHP expansion.

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[37] FfE Forschungsstelle für Energiewirtschaft e.V., Energiezukunft 2050; http://www.ffe.de/die-themen/erzeugung-und-markt/257

[38] The calculation has been made by the VIK Verband der Industriellen Energie- und Kraftwirtschaft e.V., 2010, Unpublished.

In fact, the CHP expansion is closely associated with a replacement of old by new cogeneration technologies and a change in the structure of fuel away from coal to natural gas and bio-energy. These three developments,

- replacement of separate generation by cogeneration

- replacement of old by new cogeneration technologies

- replacement of carbon-rich by low-carbon fuels, can be usefully seen only as an integrated process.

To account for the uncertainties in particular with regard to fuel shares and technology development, a window of possible developments with an upper value and a lower value of emission reduction and savings has been determined. The different levels of results are due to assumptions about key parameters such as current share of electricity from cogeneration, which is replaced by electricity from new or retrofitted units, fuel shares in the replaced CHP plants, power plants and boilers as well as in the new CHP plants.

The results have been calculated based on the following input values: growth of CHP power production, share of current old CHP to be replaced by new installations and retrofitting, fuel efficiency and electric efficiency of new CHP and replaced CHP for different fuels, electric efficiency of replaced power from conventional power plants for different fuels, heat efficiency of replaced heat from boilers, corresponding fuel shares.

EED method

The Primary Energy Savings methodology of the EED is used at a country level for national reporting to the Commission, and at project level for determining if CHP is highly efficient. In the methodology, each cogeneration unit is compared with the best technology for separate production of heat and electricity on the same fuel on the market in the year of construction of the cogeneration unit and the harmonized reference values are determined by fuel type and year of construction.

The underlying principle is that, knowing that regularly new investments have to be made in new energy production units, it is necessary to compare CHP with the centralized production installation which could be built using the same fuel rather than assuming a displacement of a different fuel or introduction of a new fuel. It is a logical approach when looking at the decision making process of investors or a member state government. By investing in or supporting CHP, a certain electricity generating capacity will be produced by CHP and NOT by centralized production based on the same fuel (= principle of ‘avoided production’).

For the timeframe of the roadmap (between 2010 and 2030), and especially in countries where there is no overcapacity, it is relevant to compare installing a certain capacity (at national level) of CHP compared to installing new capacity with another technology (power plant + gas boiler). Older installations being replaced with state-of-the-art technology.is a typical reinvestment decision. New CHP-plant (or combination of smaller installations) would not necessarily lead to less production in older production installations, but would rather preempt investments in e.g. new CCGT investments.

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