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SMALL SCALE CHP IN INDUSTRY

THE VIABILITY OF SMALL SCALE CHP APPLICATIONS IN THE GREEK INDUSTRY

ENERGY SYSTEMS AND THE ENVIRONMENT

UNIVERSITY OF STRATHCLYDE

ABSTRACT

The aim of this project was to provide insight and highlight the course and future potential of small scale CHP in the industry during the recent years, and prove its viability in the Greek Industry, stressing cogeneration's positive and negative aspects –both inherent and external. For this purpose, a literature review was undertaken which included its historical course and the identification of its inherent characteristics. The external factors influencing small-scale cogeneration were then identified and a case study involving a Greek Company was undertaken. The viability of industrial application was examined through calculations according to the Simple Pay Back Period method.

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1.0 - AIMS OF THE PROJECT

The aim of this project is to highlight the course and future potential of small scale CHP in industry during the recent years, and prove the viability of industrial applications in the Greek Industry, emphasizing on its positive and negative aspects –both inherent and external. While the presence of cogeneration in Greece dates back to **1970**, examples of use of *small scale* CHP in Greece are scarce; therefore we must confine our study to the description of the likely future of this technology in the Greek Industry.

Our estimations will be based on the projection of figures for cogeneration in general, but adapted according to the parameters belonging to the "small scale" case. As it is impossible to collect up to date figures and statistics for the whole of the countries utilizing cogeneration, we will confine our study to the latest available figures and statistics from the Greek Industry and the European region, hoping to "see the world in a grain of sand".

1.1 - CONTRIBUTION

This report focuses on the benefits that can be attained from the correct use of small scale CHP, both environmental and economic. The analysis serves as a means of highlighting some of the factors that influence the penetration of small-scale cogeneration. The identification of these factors and their weight is the first step towards the implementation of a more coherent strategy, if the European Commission and national energy authorities wish for small-scale cogeneration to have a future in the context of sustainable development.

1.2 - CASE STUDY – ETEM S.A.

In order to understand the very small presence of small scale CHP in the Greek industry, a case study was undertaken. The case study involved the Greek company ETEM S.A. - a company that specializes in aluminium extrusion - located in Attiki, Greece. Its purpose was to prove the viability of small CHP systems in modern industry under the existent regulatory, economic and market conditions. It consisted of firstly proving the load a typical unit can replace and then the economic benefits that this venture can bring for the Company.

1.3 - DEFINITIONS

CHP

Combined Heat & Power is the general term for a set of technologies whose common characteristic is that of generating both electrical power and heat using fossil fuels. The heat produced from the electricity generating process (for example from the exhaust systems of a gas turbine) is captured and utilized to produce high and low level steam. The steam can be used as a heat source for both industrial and domestic purposes or be used in steam turbines to generate additional electricity (combined cycle power)

Small Scale CHP

CHP Units whose electrical generation output is **$<1MW_e$**. Small-scale CHP typically converts about 30% of the input fuel energy into electricity and **50%** into usable heat. The definition of ‘small scale cogeneration’ comprises, of micro-cogeneration and distributed cogeneration units such as cogeneration units supplying isolated areas or limited residential, commercial or industrial demands. Extensive nomenclature can be found in Appendix B of the report.

2.0 - HISTORICAL REVIEW

Combined heat and power systems generate electricity and thermal energy in a single, integrated system. The thermal energy recovered in a CHP system can be used for heating or cooling in industry or buildings. Because CHP captures the heat that would otherwise be rejected in traditional separate generation of electric or mechanical energy, the total efficiency of these integrated systems is much greater than that of separate systems.

CHP is an economically productive approach to reducing air pollutants through pollution prevention, whereas traditional pollution control achieved exclusively through flue gas treatment provides no profitable output and actually reduces efficiency and useful energy output.

THE EARLY YEARS

Hot-air cogeneration can be traced back to medieval smoke jacks. Steam cogeneration was first applied to the steam jack, which appeared in the early seventeenth century. By the late eighteenth century, waste steam from manufacturing processes was used to power steam engines, and the hot condenser water was used again for other process purposes.

THE 20TH CENTURY

U.S. At the turn of the century in the United States, CHP systems were the most common electricity generators. However, as the separate electric power industry improved in terms of cost and reliability, users abandoned on-site electric generation in favour of more convenient purchased electricity. By 1978, cogeneration's share of electricity use had fallen to only 4%.

In the late 1970s, after the energy price increases resulting from the 70's two energy crises, the interest in CHP was renewed. The 1980s saw a rapid growth of CHP capacity in the United States. Installed capacity increased from less than 10 GWe in 1980 to almost 44 GWe by 1993. Most of this capacity was installed at large industrial facilities such as pulp and paper, petroleum, and petrochemical plants. These plants provided a "thermal host" for the electric generator.

EUROPE

The history of cogeneration in Europe is closely associated to the history of European energy policy. The factors influencing policy development are the ones affecting CHP's' status and evolution.

According to the European CHP directive final proposal, today, “roughly 40% of electricity from cogeneration is produced for public supply purposes, often in connection with district heating networks. The remaining 60% are generated by auto-producers, normally for industrial processes.”

Those countries which have developed it most strongly (for example the Netherlands and Denmark), or which have made most progress in recent years (for example, Italy and Spain) have done, so far as there has been a political will to ensure that cogeneration can move forward.

THE FUTURE

European Union countries, on average, obtain approximately the same amount of their electricity from CHP as the United States (9%), so the market interest in CHP has gained in strength in many European countries. The market interest is driven and motivated by the imposed legislation. There are several issues, which favour the expansion of cogeneration.

The European Union is extremely dependent on its external energy supplies, with imports currently accounting for 50% of requirements. This figure is projected to rise to 70% by 2030 if current trends persist. The European Union has limited scope to influence energy supply conditions. It is essentially on the demand that the EU can intervene, mainly by promoting energy savings in buildings and in the transport sector. At present green house gas emissions in the European Union are on the rise making it difficult to respond to the challenge of climate change and to meet the commitments under the Kyoto Protocol.

Within the EU, cogeneration is at a relatively low level and is a long way from reaching its full potential. However, through recent policy development within the EU, it is believed that CHP can play a significant role towards a more “environmentally conscious” energy sector.

Estimations referring to cogeneration’s growth vary significantly. According to the European project “ATLAS”, growth from the present 10% of electricity production to about 30%, is an achievable target for the year 2010. On the other hand, according to CHP statistics taken from Eurostat 2001, from 1994 to 1998 the percentage growth was a poor 2%. The share of CHP electricity is assumed to be 18% of total EU electricity generation projected in European Union Energy Outlook to 2010.

Examining each EU member individually, we see that whereas members such as Sweden and Austria report cogeneration shares of 96% and 76% respectively, in countries such as Ireland and Greece, cogeneration only plays a marginal role with contributions around 2%. The climatic differences among Member States is one of the most important factors explaining the huge differences of penetration of cogeneration and underline the relevance of the principle of subsidiarity.

2.1 - CHP TECHNICAL PARAMETERS

COMPONENTS

The main components of the a small-scale cogeneration system are:

- a prime mover (usually an internal combustion engine)
- an electricity generator (driven from the prime mover)
- a heat recovery system
- a control system
- an exhaust system, and
- an acoustic enclosure.

Cogeneration systems are usually classified according to the prime mover component. Typical small CHP units include steam turbines, gas turbines, microturbines, reciprocating engines and fuel cells. Their application differs according to the environment in which they operate. Typical choice for residential and industrial applications is the internal combustion engine.

TECHNOLOGIES

RECIPROCATING ENGINES

Such equipment includes spark ignition (natural gas, gasoline, biogas), compression ignition (diesel) and dual fuel types. Their efficiency ranges between **25** and **40%,** reaching an overall efficiency of **80%.** This type of cogeneration unit is considered the cheapest and fastest selling. Their exhaust gas temperature reaches **850 F** while the coolant high temperatures are in the range of **150 - 250 F.**

GAS TURBINES

Gas turbines burn fuel (gas of liquid) at high pressures. Their rotary motion is produced by the expansion of the hot products of the burning process through the turbine blades mounted on the shaft. This rotary motion in turn drives an electric generator and a separate steam generator recovers the exhaust gases. Their efficiency range is similar to the above although the thermal recoverable energy is considerably higher. The exhaust gases have a temperature in the range of **900 – 1100 F**. Another advantage is their production of high-grade steam.

MIRCOTURBINES

Microturbines are a smaller version of the above technology. Their efficiency range is **25 – 30 %** and their exhaust gas is at a temperature of **500 F**. They are usually preferred due to their fuel flexibility, small size and low maintenance costs.

FUEL CELLS

The output of a fuel cell cogeneration unit is DC Power as the electricity component and heat and water as the by-product. Most of the fuel cell technologies (solid oxide, molten carbonate, proton exchange membrane) are still at the experimental stage and only one – the phosphoric acid or PAFC - has reached the commercial stage as yet. The efficiency of these units is between **38** and **45%** and its operating temperature is approximately **480 F**. The relatively high cost **(>3.500$/kW)** renders such a solution less competitive. However future development in the above technologies may alter the market and provide new incentives for the buyers.

FUEL

The table below indicates emissions of each of the most dominant types of fuel in the Energy sector.

- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

Considering cogeneration's role as an environmentally friendly means of energy production, it would seem inconsistent if the trend for fuel choice did not reflect this. As such, in the context of sustainable development, the development in the use of fuels for CHP shows a trend towards cleaner fuels thus enhancing the environmental benefits of CHP.

As seen from the above table, Natural Gas is the cleanest in terms of emissions, in the group. Natural Gas is an environmentally friendly fuel. During combustion, there is no emission of SO2 and, compared with coal, only **60%** of the emission of CO_2 per input unit of fuel.

However, one issue that has arisen with respect to natural gas and it's relation with greenhouse effect, is the fact that the principle component of natural gas (methane) is itself a very effective greenhouse gas. Methane, it has been proven, has an ability to trap heat almost **21** times more effectively than CO_2.

A major study performed by the American Environmental Protection Agency in collaboration with the Gas Research Institute (GRI) in **1997** sought to discover whether the reduction in CO_2 emissions from increased use of natural gas, use would be offset by a possible increased level of methane emissions. The study concluded that the reduction in emissions from increased natural gas use strongly outweighs the negative effects of increased methane emissions.

It should also be noted that the use of natural gas does not contribute notably to smog formation, as it emits low levels of nitrogen oxides, and almost no particulate matter.

Eurostat 2001 statistics have shown that Natural gas is the most dominant fuel in CHP production with a share of **45%** in **1998** compared with **30%** in **1994**. In contrast, the use of hard coal and lignite has declined from **30%** to **20%** between **1994-1998**. As an example, the table (fig.1) below indicates the percentages of use, each fuel type holds, in the Australian cogeneration sector.

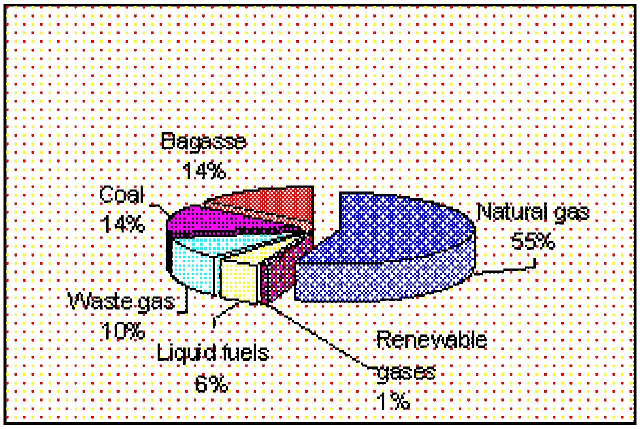

fig.1 Cogeneration by fuel type (Source: Australian Cogeneration Association)

EFFICIENCY

Increased equipment efficiency is the single most central parameter for which cogeneration is regarded as a potent player in the future of sustainable development. Advanced materials and computer-aided design (CAD) techniques have radically improved equipment efficiency and reliability while reducing costs and pollutant emissions.

It is also one property that, when calculated, must be treated with caution. The efficiency of cogeneration reaches **75-80%** when both the electrical and the heat output are exploited fully. This, however, is not always the case. Although the electrical output is more easily distributed and utilized, the exploitation of the heat output can vary according to the time of the day but also the month of the year. This difficulty arises because of the fact that energy in the form of heat must be used up near the production facility since the cost of carrying it over a distance is proportional to that distance and the financial benefits would be overweighed by the immense capital costs. One should therefore not take into account the nominal efficiency of the CHP system (i.e. the one in which both thermal and electrical output is fully utilized) but rather the average efficiency calculated over period of time, which will be representative of the actual energy used during that time.

According to Eurostat, the average overall efficiency of CHP plants in the EU was **75%** in **1998** compared with **73%** in **1994.**

2.2 - APPLICATIONS IN INDUSTRY

In the industrial sector many processes require heat in addition to electricity. Their structure according to heat requirements is as follows:

- Low temperature processes (less than **100 C**) e.g. agricultural processes, hot water use, air conditioning
- Middle temperature processes (**100-300 C**) e.g. paper industry, cloth industry, sugar industry and some chemical industries where heat is required in the form of stream
- High temperature processes (**300-700 C**) e.g. chemical industries
- Very high temperature processes **(>700 C)** e.g. cement industries, metallurgical industries

A significant potential of cogeneration arises in the following industrial branches:

- Food industry
- Cloth industry
- Paper industry
- Cement industry
- Chemical industries
- Basic metallurgical industries (e.g. aluminium production plants)

The graph below (fig.2) tabulates thermal versus electrical load needed for each of the corresponding kinds of industry, for various industries in the U.S.

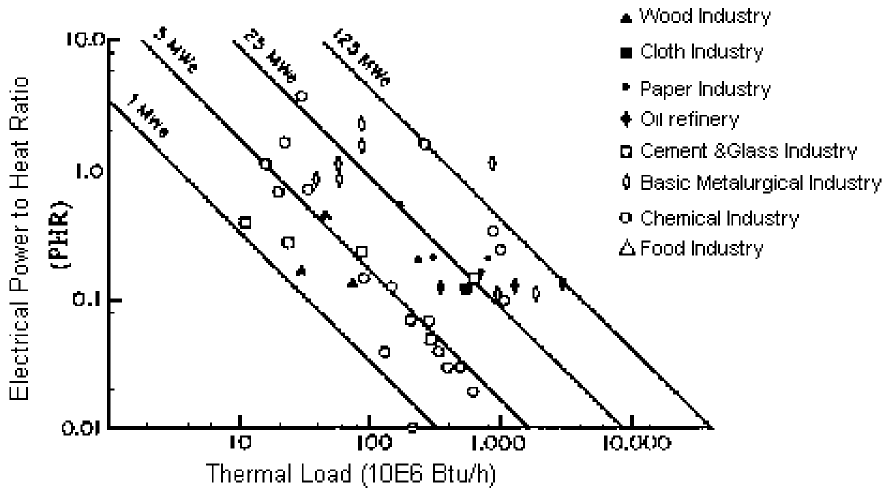

fig.2 thermal versus electrical load

Below is a table of Greek industries that have employed cogeneration units of various sizes up and fuel types.

	Industry	Location	Cogeneration Technology	Installed El. Power (MW)	Electricity production (GWh)
1	Greek Sugar Industry	Larisa	Steam turbine	12.0	16.343
2	Greek Sugar Industry	Platy	Steam turbine	12.0	12.950
3	Greek Sugar Industry	Serres	Steam turbine	6.0	11.583
4	Greek Sugar Industry	Xanthi	Steam turbine	16	10.909
5	Greek Sugar Industry	Orestiada	Steam turbine	10	12.504
6	ETMA	Athens	Steam turbine	13.1	39.067
7	Peiraikh Petraikh	Patra	Steam turbine	1.25	(*)
8		Drama	Diesel Engine	34.65	(*)
9	Ladopoulos	Patra	Air turbine	3.0	(*)
10	Halyvourgikh	Eleysina	Air Turbine	80.0	(*)
11	Motor Oil	Korinthos	Air Turbine	27.0	215.732
12	Oil Refinery of Aspropyrgos	Aspropyrgos	Air turbine + steam turbine	34.0 + 16.0	
13	Ε.Π.Β	Kavala	Air turbine + steam turbine	11.0 + 5.5	
14	Α.Ε.Ε.Χ.Π.Λ.	Drapetsona	Steam turbine	11.8	18.107
15		Kavala	Steam turbine	25.0	53.466
16	Χ.Β.Β.Ε	Thessaloniki	Steam turbine	11.0	25.400
17	Aluminium of Greece	Distomo	Steam turbine	11.6	63.316
18	Cotton Industry of Dayleia	Dayleia	Steam turbine	0.5	unknown
Total:				**346.8**	

[*] Not functional
Figures based on latest available data from the Center for Renewable Energy Sources of Greece (2000)

From the figures on installed electrical power in the above table, it becomes apparent that small-scale cogeneration has found little application in the Greek Industry thus far. It is either absent, or not functional in most cases. In this report we will try to uncover the reasons why this is so, and examine its potential. This report focuses on the more recent advances in the area of legislation and policies concerning sustainable development.

2.3 - ECONOMICS

For most similar projects the economics can be broken down to three kinds of cost.

- The initial costs (purchasing and installation)
- The maintenance costs, and
- The running costs.

INITIAL COSTS

One characteristic of cogeneration is its high capital costs. These costs for small-scale CHP applications are around **1.000 €/kWe** for more common sizes, but vary from just below **700 €/kWe** for a couple of larger units to above **3 000 €/kWe** for small units1. However, its economic attraction comes from the significantly lower running costs relative to those of a conventional boiler; i.e. the fuel price.

MAINTENANCE COSTS

The maintenance of cogeneration units is again higher than that of conventional boilers. Their increased complexity makes the cautious assessment of the maintenance costs essential. In order to facilitate the comparison between different cogeneration units, life cycle maintenance costs must be known. Life cycle maintenance costs must include the components below on an annual basis so as to enable correct comparison:

- Routine service costs
- Lubrication costs
- Overhaul costs

1 RISKS AND CHANCES FOR SMALL SCALE COMBINED HEAT AND POWER IN THE LIBERALISED ENERGY MARKET MAY 2001

PROJECT EVALUATION TECHNIQUES

The most common techniques employed to evaluate different cogeneration projects are the Simple Payback Period technique and the Payback using Discounted Cash Flow Analysis. The first is the ratio of the capital cost to the annual savings. The second is a more complicated method, which takes into account the effects of future revenues and costs, and also accounts for the change in monetary value over time.

FINANCING OPTIONS

Several options have become available to suit the accounting policy and capital availability of different companies. The most frequently used are:

- Outright purchase
- Equipment supplier finance
- Contract energy management

While outright purchase is the simplest and involves the purchase of equipment and responsibility for the maintenance and overhaul costs, other options such as equipment supplier finance may make more sense for a company with insufficient capital availability. This method involves the cogeneration company being responsible for the installation and maintaining the plant free of charge while the client pays for the fuel thus benefiting from the resultant discounted electricity price. Contract Energy Management is a financial scheme - comprising of the leasing of equipment and other options, which can vary – agreed with a CEM company.

3.0 - DISCUSSION

The overall efficiency and sustainability of cogeneration is dependent on many factors, such as technology used, fuel types, load curves, the size of the unit, and also on the properties of the heat. For practical reasons and based on the fact, that the use of the heat output for different purposes requires different temperature levels of the heat, and that these and other differences influence efficiencies of the cogeneration, cogeneration could be divided into classes such as: ‘industrial cogeneration’, ‘heating cogeneration’ and ‘agricultural cogeneration’.

Several factors that come into play when discussing the matter of cogeneration in industry are:

- Protection of the environment.
- New technologies.
- Relating policies.
- Industry’s reaction and implementation of the policies.
- The effect of pressure groups, organizations and equipment manufacturers.

In order to understand the dynamics of the diffusion of CHP in the industry sector, we must first establish an understanding on the nature of interaction among these factors. Here (fig.3) we see a simple illustration their interactions:

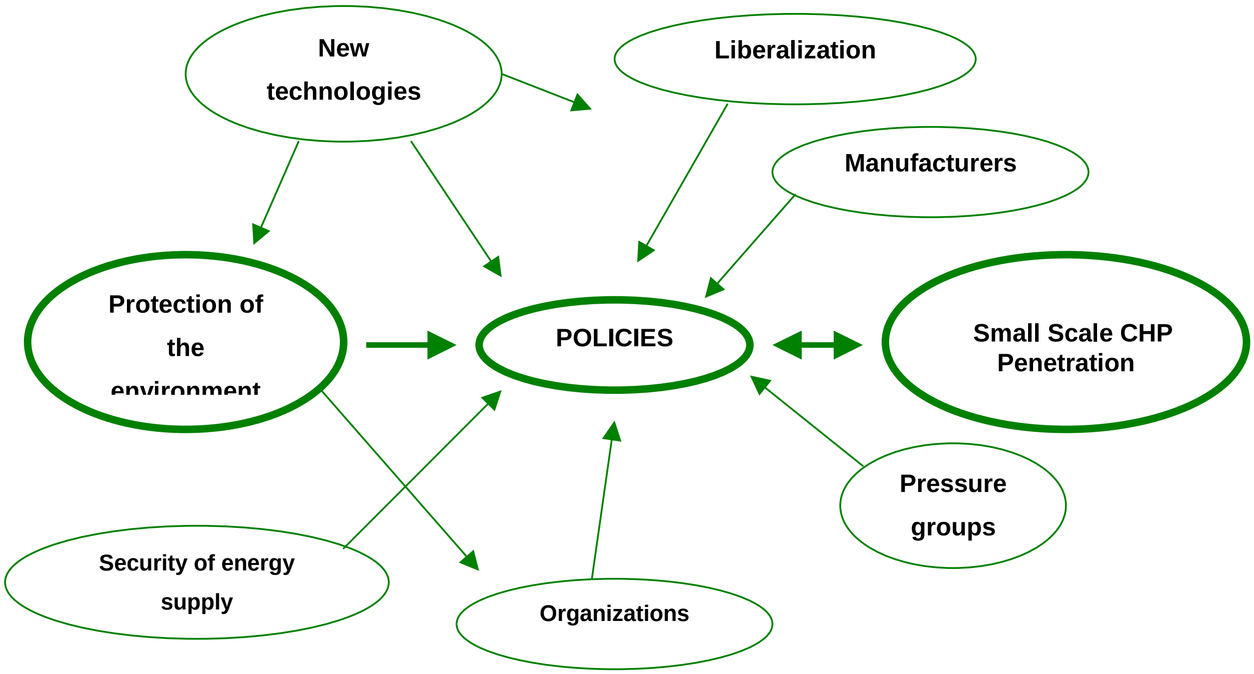

Fig. 3 Interaction of influencing factors

Each of these factors will be analyzed in this report so that we can identify the driving -and opposing- forces behind the implementation of small scale CHP in Industry.

3.1 - PROTECTION OF THE ENVIRONMENT

The concept of environmental protection: for the purposes of this paper, the definition of environmental protection is the one given by the European Commission's guidelines, which takes environmental protection to mean any action designed to remedy or prevent damage to our physical surroundings or natural resources, or to encourage the efficient use of these resources. The Commission regards energy-saving measures and the use of renewable sources of energy as action to protect the environment. Energy-saving measures should be understood as meaning among other things "action which enables companies to reduce the amount of energy used in their production cycle".

It is recognized that progress is frequently brought about by change. Change not merely in the implementation of the existing methods, but of a more radical kind -that of mentality. In the years leading up to the present, the trend was that of economical progress –whatever the cost- as a means of attaining prosperity and a better standard of living. This lead to the environment being treated purely as a source of energy and a sink for waste -such as chemical substances and heat- from the production of goods.

The results to the environment gave a terminal blow to the suitability of this approach as a means of achieving a good living standard, and by the end of the 20th century, environmental consciousness had developed enough -and had become an integral part of the politicians vocabulary- to ultimately give rise to the concept of "sustainable development". This term was fully defined by the World Commission on Environment and Development, in 1987, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The European Commission's paper 'A Sustainable Europe for a better world — A European Union Strategy for Sustainable Development' presented at the Gothenburg European Council on 15 and 16 June 2001, in stating the main threats to sustainable development identified climate change as one of the principal barriers. The threats concerning the environment are listed here:

- Emissions of greenhouse gases from human activity are causing global warming. Climate change is likely to cause more extreme weather events (hurricanes, floods) with severe implications for infrastructure, property, health and nature.

- Severe threats to public health are posed by new antibiotic-resistant strains of some diseases and, potentially, the longer-term effects of the many hazardous chemicals currently in everyday use. Threats to food safety are of increasing concern.

- The loss of bio-diversity in Europe has accelerated dramatically in recent decades. Fish stocks in European waters are near collapse. Waste volumes have persistently grown faster than GDP. Soil loss and declining fertility are eroding the viability of agricultural land[2].

The paper on sustainable development set the tone for the strategies to be crafted in order to successfully tackle the posed threats. As such, these concerns have materialized as specific policies over the last couple of years. One of these - and the most relevant to this report - is the directive of the European parliament of **2004**, on the promotion of cogeneration. The results of this directive are still to be evaluated for their effect.

In this brief description below, we can see how cogeneration can be effectively used as a means of increasing energy efficiency and taking action in protecting the environment. Replacing simple boilers by small-scale CHP plants results in a reduction of fuel consumption and thus a reduction of emissions of harmful substances, i.e. smaller emissions of the greenhouse

[2] COMMISSION OF THE EUROPEAN COMMUNITIES: A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development. - Brussels, 15.5.2001

gas carbon dioxide, sulphur dioxide, and nitrogen oxides. The CO2 reduction is particularly important because unlike SO_2 and NOX, CO_2 cannot be removed with existing clean-up technologies.

The size of the CO_2-reduction depends on the fuel used, the type of plant and the form of power and heat production, which it replaces. If coal is replaced by natural gas, the same quantity of input energy will contain about **40%** less CO2. The amount by which the CO_2 emissions, is reduced depends on the type of power production that is replaced. The largest reduction is achieved when the electricity produced at small-scale CHP plants replaces electricity produced at coal-fired stations without co-generation of heat.

However energy efficient and competitive small-scale CHP pants are, the main drive that opens a market for such solutions is the protection of the environment. This strong drive activates policy makers across the globe, which in turn gives incentives for the end users such as -in our case-industries.

3.2 - POLICIES

It can be seen that the foundation of the European energy policy is built on factors like Environment, Security of Supply and Energy Conservation and Competitiveness, where much emphasis is always on Environment. Cogeneration is one technology that has the possibility to meet all these basic demands, which lead to self-promotion as a favorable choice for cleaner and efficient energy production technology.

One of the first steps taken by the European Commission towards encouraging environmental protection and sustainable development in the Industry, is the creation (and the extension of their validity up to December **2000**) of a set of "guidelines on State Aid for Environmental Protection" proposed in **1994.** In these guidelines "The Commission regards energy-saving measures and the use of renewable sources of energy as action to protect the environment. Energy-saving measures should be understood as meaning among other things action which enables companies to reduce the amount of energy used in their production cycle[3]."

We do not come across cogeneration in this document since the definition of renewable energy sources is: "renewable non-fossil energy sources, viz. wind energy, solar energy, geothermal energy, wave energy, tidal energy, hydroelectric installations with a capacity below **10 MW** and biomass, where biomass is defined as products from agriculture and forestry, vegetable waste from agriculture, forestry and the food production industry, and untreated wood waste and cork waste."2

However, the paper goes on to say that investments in the combined production of electric power and heat may also qualify under these guidelines if it can be shown that the measures beneficial in terms of the protection of the environment because the conversion efficiency is high, because the

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[3] Community guidelines on State aid for environmental protection, Official Journal of the European Communities (2001/C 37/03)

measures will allow energy consumption to be reduced or because the production process will be less damaging to the environment. As a result in concludes that investment in CHP may be given aid at the basic rate of 40 % of eligible cost.

In its Resolution of **15 November 2001** on the Green Paper entitled "Towards a European strategy for the security of energy supply", the European Parliament calls for incentives to encourage a shift towards efficient energy production plants, including combined heat and power. In this paper, cogeneration is also identified as a means of securing energy supply.

Nevertheless, in its Resolution of **25 September 2002** on the Commission communication on the implementation of the first phase of the European Climate Change Program, the European Parliament welcomes the idea of submitting a proposal to strengthen Community measures to promote the use of combined heat and power (CHP) and calls for prompt adoption of a Directive on the promotion of CHP. I.e. despite the fact that cogeneration is fossil fuel powered, it is finding its place among the environmentally friendly technologies that can play a part in sustainable development.

As a result of the above tendencies, what we have is the directive of the European parliament on the promotion of cogeneration based on a useful heat demand in the internal energy market, which is the latest and probably most relevant step for the promotion of cogeneration in general. In this, we find the definition of small-scale cogeneration. "The definition of 'small-scale cogeneration' comprises, inter alia, micro-cogeneration and distributed cogeneration units such as cogeneration units supplying isolated areas or limited residential, commercial or industrial demands[4]."

[4] DIRECTIVE 2004/8/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 February 2004on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC.

Efficiency criteria for cogeneration in general are not yet integrated in the specific policies that are aimed at promoting cogeneration. In article **4** of this **2004** directive, we see that the determination of these criteria is to be completed “not later than **21 February 2006**”.

3.3 - LIBERALISATION

The interconnection of small scale CHP and deregulation comes from the fact that the deregulation of the energy market could indeed lead to a diffused generation system, instead of the previous centralized & nationalized generation, bound to big systems, thus increasing the interest for small scale CHP. The "diffused generation" concept is more satisfactory to the needs, which European countries are actually facing:

- Efficient use of resources.
- Flexibility/autonomy/self-sufficiency/security of the energy system.
- Respect for the environment (Kyoto protocol: reduction of CO_2 emissions).

With the liberalization of the energy market (both electricity and gas), it is generally expected that small-scale cogeneration systems could have an increasing trend in installations. In theory, the liberalized environment opens new possibilities in the area of diffused generation. However, in practice liberalization in certain countries like Greece has been slow and conclusive results on the effect of this are yet to be identified.

According to an independent study supported by the European Commission, the process of liberalization has hindered the installation of small-scale CHP units in Italy. The first steps towards liberalization **(1997)** have led to the uncertainty of the validity of the previous legal framework, with a delay of a few years for a new legislation[5].

[5] SAVE Project: RISKS AND CHANCES FOR SMALL SCALE COMBINED HEAT AND POWER IN THE LIBERALISED ENERGY MARKET

4.0 - CHP IN GREECE

A look at the general picture of cogeneration in Greece should give us a clue as to the mentality of the government (and the PPC) and it's willingness to endorse alternative industrial solutions like small scale CHP.

The share of CHP electricity production in Greece is about **3,4%,** one of the lowest in the European Union. CHP in Greece is developing slowly. Most of the cogeneration plants were built between **1970-1980** without economic incentives. Since **1990,** PPC have converted some power stations in cogeneration mode and its behavior toward cogeneration is becoming much more positive. Additionally, the situation for the development of CHP is improving 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.

CHP in electricity generation and in heat production

The food sector is the most relevant in terms of number of CHP plants, but in terms of capacity the refinery sector is not far behind. In the past, the most efficient CHP installations were the refineries, because of their continuous operation, the low-cost fuel (distillery by-products) and the superior power-to-heat ratio.

Very few installations exist in the commercial sector. Case studies for specific projects have shown that cogeneration investments in this sector are not viable, unless the produced heat is used also for cooling purposes during the summer (trigeneration).

Sector	Maximum Capacity			Production			Fuel	Number of units
	Electrical		Heat	Electricity		Heat	Input	
	CHP=Gross MW	Gross MW	Net MW	ECHP/Gross GWh	Gross GWh	Net TJ	TJ (NVC)	
Public supply	495	495	120	147	2132	1174	21844	2
Auto-producers	211	211	790	990	990	10386	18872	32
Refineries	99	99	201	635	635	3394	7310	7
Non ferrous metals	14	14	85	54	54	1270	1947	3
Chemical industries	36	36	106	156	156	2043	4821	6
Food products, beverages and tobacco.	50	50	331	110	110	2944	3719	14
Textile, clothing and leather.	13	13	67	36	36	736	1077	2
TOTAL	**706**	**706**	**910**	**1137**	**3122**	**11560**	**40717**	**34**

Table 4: CHP units' capacity and production by sector6.

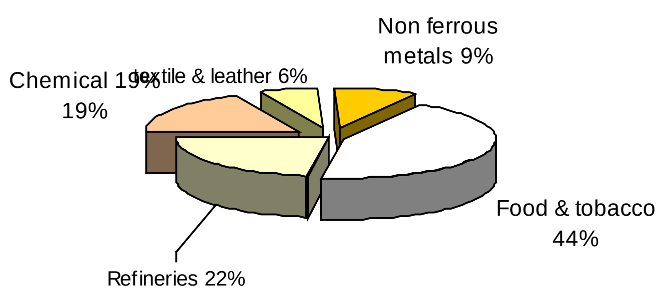


Diagram 5: CHP by sector in Greece

[6] Statistics from Institute Wallon and CEREN for year 2000. Based on the data collected by the Public Power Corporation (ΔΕΗ). Kindly offered by the Hellenic Chp Association HACHP.

4.1 - FUELS UTILIZATION

In diagram 6 we see the electricity generation in Greece by fuel source. Lignite is the only Greek domestic fuel source, with **82%** of the total local energy production and represents the main fuel alternative choice to ease the impact of oil in the country's economy. Lignite accounted for **64%** of the total electricity generation in **2001** and is used almost exclusively for steam-electricity power generation.

Oil is also an important fuel source in Greece accounting approximately for **63%** of the total energy consumption. Natural gas consumption is increasing significantly and according to calculations made by the International Energy Agency (IEA) is expected to triple over the next **10** years. Renewable energy represents **8.1%** of total electricity generated in Greece. The European directive on the promotion of renewables has set a target of **16%** by **2010**.

Biomass is a fuel with special potential, due to the considerable amounts of agricultural and forest residues produced in Greece. There are three biomass CHP plants in Greece, producing **179 GWh** of electricity per year. Regarding CHP, most of the CHP systems operating in Greece today are industrial power plants burning oil. Few units, operated by PPC, burn lignite and provide District Heating (DH) in the northern part of the country. Natural gas is the fuel of choice for IPP and auto-producers. **58%** of the auto-producers fuel input is natural gas.

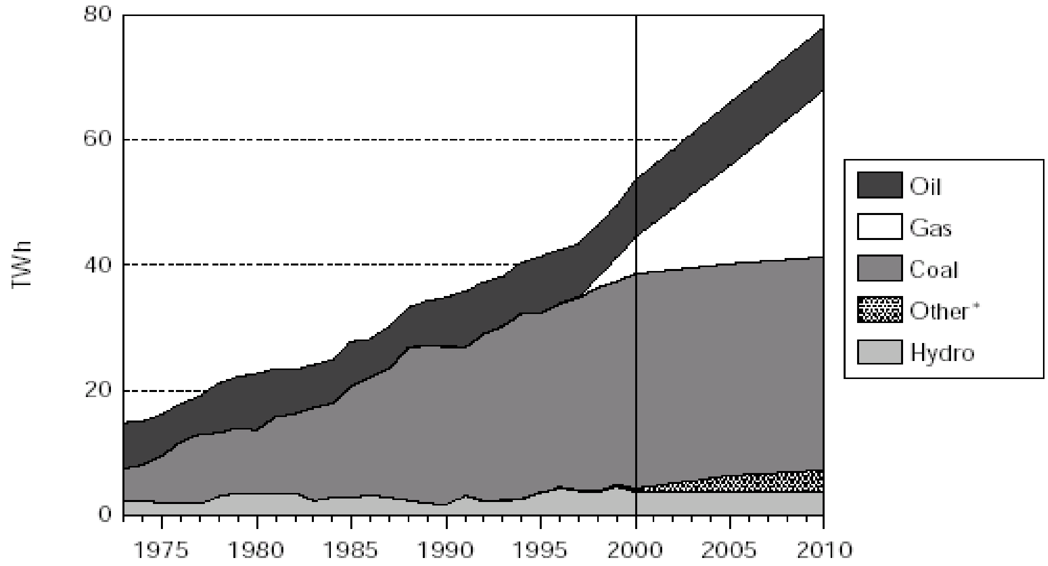


Diagram 6: Electricity generation by fuel source

Type of fuel	Maximum capacity			Production			Fuel	Number of units
	Electricity		Heat	Electricity		Heat	Input	
	CHP MWe	Gross MWe	Net MWe	ECHP GWh	Gross GWh	Net TJ	TJ	
Solid	495	495	120	147	2132	1174	21844	2
Liquid	97	97	423	415	415	5178	8075	14
Gas	114	114	368	575	575	5207	10798	18
TOTAL	**706**	**706**	**910**	**1137**	**3122**	**11560**	**40717**	**34**

Table 7: Operational CHP unit's capacity by fuel type[7]

[7] Data from the Hellenic CHP Association (HACHP)

Fuels		Units	Public Utilities	Auto-producers	Total
Lignite and derived products	Fuel input	TJ (NCV)	21844		21844
	Gross electricity generation	GWh	2132		2132
	Net heat production	TJ	1174		1174
Natural gas	Fuel input	TJ (NCV)		10798	10798
	Gross electricity generation	GWh		575	575
	Net heat production	TJ		5207	5207
Other fuels	Fuel input	TJ (NCV)		8075	8075
	Gross electricity generation	GWh		415	415
	Net heat production	TJ		5178	5178
TOTAL	Fuel input	TJ (NCV)	**21844**	**18872**	**40717**
	Gross electricity generation	GWh	**2132**	**990**	**3122**
	Net heat production	TJ	**1174**	**10386**	**11560**

Table 8: Operational CHP units' fuel input and heat - electricity production[5]

4.2 - ELECTRICITY PRICE

Prices for electricity purchase from CHP producers are calculated on the basis of the sales price that the power utility adopts. Recently, the Public Power Corporation (PPC) transformed from a highly integrated and state owned entity, which has been subjected to the Greek Government, to a private company, satisfying all the requirements set by the EU. Still though, Greece has the lowest domestic electricity prices in Europe with an average of **6.3 € per 100 kWh**, even lower for industry, depending on the consumption and agreement. On the other hand, the domestic sector represents **33%** of the total electricity consumption and the industrial sector **31%,** hence **64%** of the total electricity consumption is sold at a very low price.

The average rate of increase for the price of electricity during the recent years has being considerably higher for the commercial sector (+ **11 Euro / year**) than for the remaining sectors, despite the fact that the former accounts for only **25%** of the total electricity consumption.

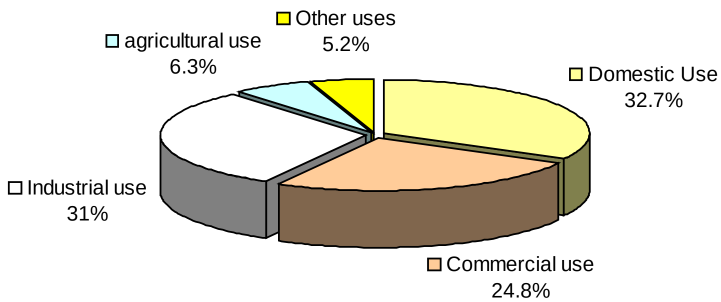


Diagram 9: Greek electricity consumption by sector (Public Power Corporation S.A.)

4.3 - SELLING TO THE GRID

PPC is obliged to buy all the electricity from independent power producers (IPP) and additional electricity from auto-producers at the following regulated price:

- For renewable CHP, the price equals to **90%** of the PPC energy invoice for the energy component and **50%** of the power invoice for the power component.
- For conventionally fuelled CHP, the electricity price paid by PPC will equal to **70%** of the energy invoice for the energy section plus **50%** of the PPC power invoice for the power section.
- For CHP auto-producers, the electricity purchase price equals to the PPC energy invoice for the energy section.

The price offered by PPC to the cogenerators is a direct function of the voltage at which each cogenerator is connected to the national grid. If a cogenerator is connected to the high-voltage network, that automatically provides very low purchasing prices to the cogenerator. From this it follows that it is difficult for cogeneration projects in general to become financially viable.

Industrial consumer	Annual consumption kWh	Maximum demand kWh	Annual Utilisation (In hours)	Euro/ 100 kWh	
				With taxes	Taxes excluded
IA	30.000	30	1000	9.40	8.70
IB	50.000	50	1000	9.40	8.70
IC	160.000	100	1.600	8.60	8.00
ID	1.250.000	500	2.500	6.90	6.40
IE	2.000.000	500	4.000	6.40	5.90
IF	10.000.000	2.500	4.000	6.40	5.90
IG	24.000.000	4.000	6.000	5.40	5.00
IH	50.000.000	10.000	5000	5.00	4.60
II	70.000.000	10.000	7000	4.40	4.10

Table 10: Electricity prices for industry

4.4 - FUEL PRICE

Natural gas is the most technically and financially appropriate fuel for CHP projects and this trend is going to be maximized in Greece, where the Government encourages the penetration of gas, in order to reach national environmental and security of supply targets. The main difficulty is that, due to the isolation of Greece from other EU States and the difficult international relations with bordering countries, gas sources are scarce and the supply of gas for power generation tight.

Security of supply concerns have lead to a high degree of state intervention on the energy sector, what is causing problems of transparency on fuel prices. The activities of the Public Gas Corporation (DEPA) are not regulated because Greece has temporally postponed the Directive 98/30/EC up to 2006. Therefore, there are not regulated tariffs and gas prices are based in bilateral contracts with DEPA.

The Public Power Corporation (PPC) has a special contract for the purchase of gas with DEPA with more favorable terms than the rest of gas consumers. This "most favored customer contract" began in **1998** and it has duration of 16 years. The exact terms of this contract are not publicly available. Despite the above situation, DEPA and the Attica region gas supplier (EPA Attiki) have provided the following reference gas prices for CHP independent power plants:

LOAD FACTOR	€/MWh
60%	20.18
70%	19.71
80%	19.12
90%	18.88

Table 11: Low-pressure gas price for the industrial sector in the Attica area

According to DEPA, if the oil prices remain equal to the **2002** average, it is expected that in **2003-2004** the cogeneration prices will drop by **2-5%** especially for high load factor consumers. DEPA is currently studying the structure of a new tariff price for gas to be applied after the market liberalization, when TPA to DEPA's gas system will be granted. The gas market liberalization is expected to happen in **2006,** however the major changes in tariff price are expected not earlier than **2009**.

Lignite is at the present the most used fuel for power generation. Yet, the Public Power Corporation, which has the **97%** of the total power installed capacity, control its own lignite supply and have widely used this fuel to run away from oil import dependency. There is not a price reference for this fuel but it is very likely that the CHP public installations will get a special price as a result of the vertically integrated structure of PPC.

5.0 - INDUSTRIAL APPLICATIONS

In this part of the report we shall try examine a specific case study. From this case study and the insight we have acquired for the status of cogeneration in Greece, we will try to export useful clues on the viability of such technology in the industrial sector of this country.

During the research prepared for this report, very few examples of small scale CHP application in industrial sites outside Greece – for which there was adequate information - were found. One application in Italy, and one in Switzerland.

5.1 - CASE STUDY - ETEM S.A.

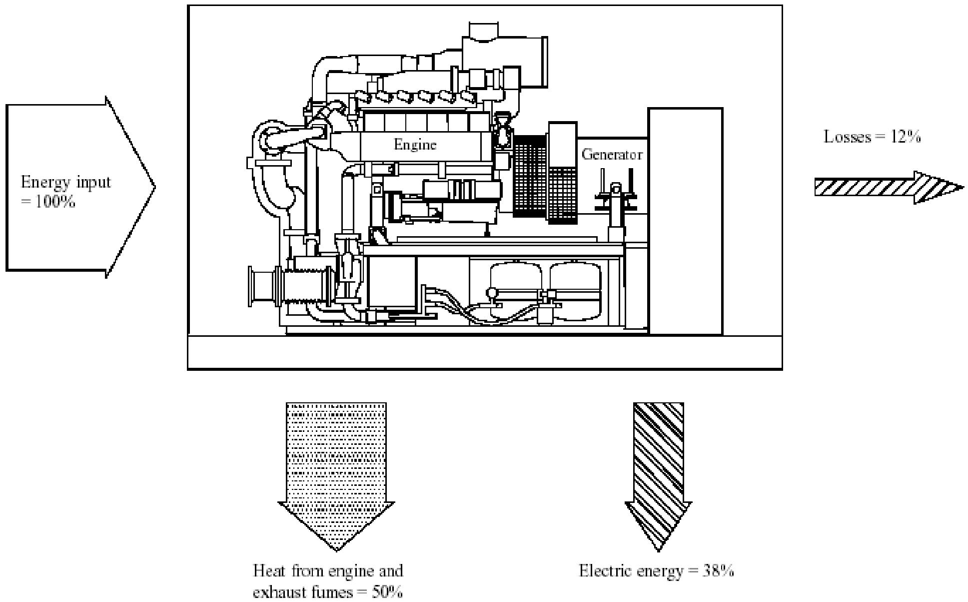


Figure 12: Energy balance of a typical CHP unit

For the needs of this report and in order to explore the possibilities of such applications in the Greek Industry, the Greek company ETEM S.A. was chosen as a candidate in order to examine the viability of operation of a typical small scale CHP unit. During the summer months of **2002** while working for this company, the management was kind enough to allow access to the company's energy demand data. ETEM S.A. is an aluminium extrusion Industry specializing in aluminium profiles for architectural systems and composite panels. One of the largest Greek companies in the field of aluminium extrusion, ETEM recently became official supplier of German carmaker industry BMW.

In Magoula, Attiki, lies ETEM's principal factory, whose operation includes profile extrusion, panel construction and aluminium profile electrostatic painting. Using energy demand figures together with figures on fuel prices, CHP unit costs and certain assumptions that were made and will be stated below, a feasibility study was prepared.

The state aid given for such a venture in Greece (at that time) amounts to **35%** of the capital cost of the CHP unit as well as a natural gas tariff that is lower to the one used for powering boilers instead of a cogeneration unit (**0.0141** Euro/kWh and **0.0103 Euro/kWh** respectively). The study was limited to the range of reciprocating engine driven CHP units because of the experience from the above installations in Italy and Switzerland. For this factory, figures for the average hourly thermal and electrical demand and for the hours of operation were obtained. The optimal size of the unit was chosen after considering electrical and thermal loads and on the basis of satisfying thermal demand. Availability of equipment was also considered, hence the CHP unit had to be available in the Greek market. The proposed CHP unit that was chosen had a capital cost of approximately **340.000** Euro and an annual maintenance cost of **18.000** Euro. Charts for the contribution of the CHP unit to the demand in energy are plotted. Also, a chart was plotted that depicts the heat rejected when the demand was lower than the thermal capacity of the unit, and the additional heat required when the demand for thermal energy exceeded the unit's thermal capacity.

Calculations (see Appendix A) were made for:

- The annual cost of energy in the case of using the conventional methods,
- The annual cost of energy in the case of using the CHP unit instead,
- The net total savings per Annum and hence,
- The simple pay back period.

5.2 - RESULTS

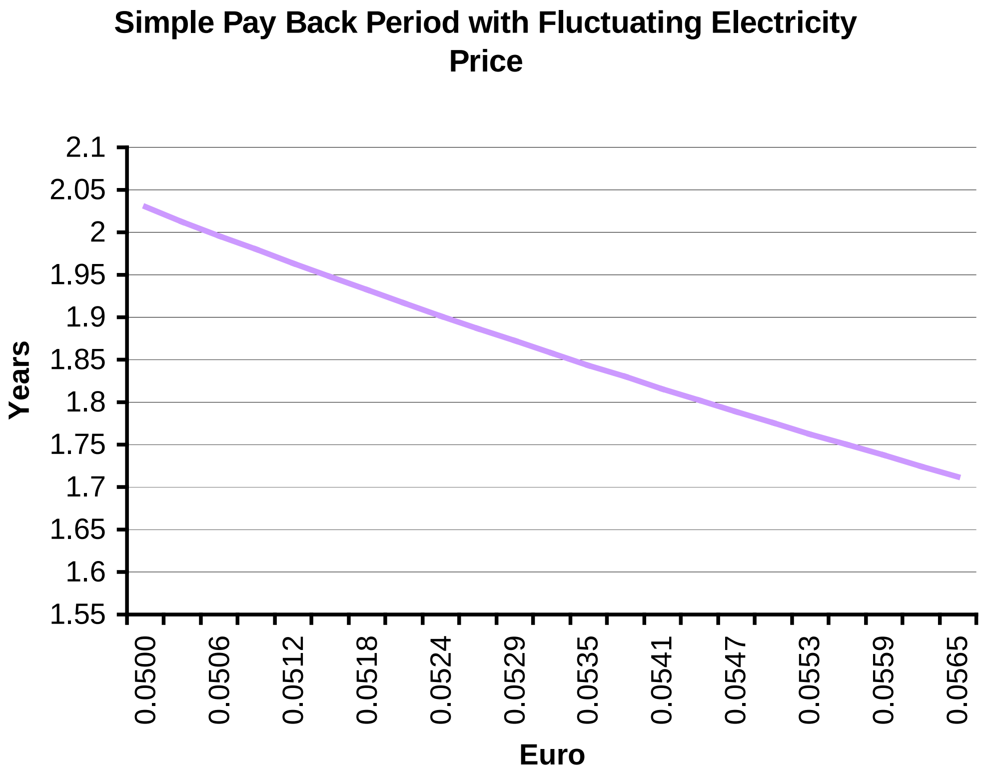
The simple pay back period for the proposed unit was calculated to be **1.91 years**. The study was restricted to simple cogeneration. However the prospect of trigeneration could possibly drive the pay back period even lower. In chart C of the Appendix (Grey areas represent top up heat from boilers whereas black areas represent rejected heat) we see that the heat rejected during the summer months could be instead used if the air-conditioning system of ETEM’s offices situated near the factory was coupled to the CHP unit.

5.3 - SENSITIVITY STUDY

From the feasibility study it is clear that such a project could – under the existing circumstances - become a viable and very attractive alternative to the conventional separate production of heat and electricity. For the purposes of the project, a sensitivity study was undertaken, based on the input data of the above case study, in order to make predictions about the future of small scale CHP. The price of natural gas and electricity were altered within the boundaries suggested by the above statistics and figures on the Greek energy market. Based on the output of this sensitivity study, we will try to make predictions about the future of small-scale cogeneration applications in the Greek Industry, The calculations of the study can be found in Appendix B of the report.

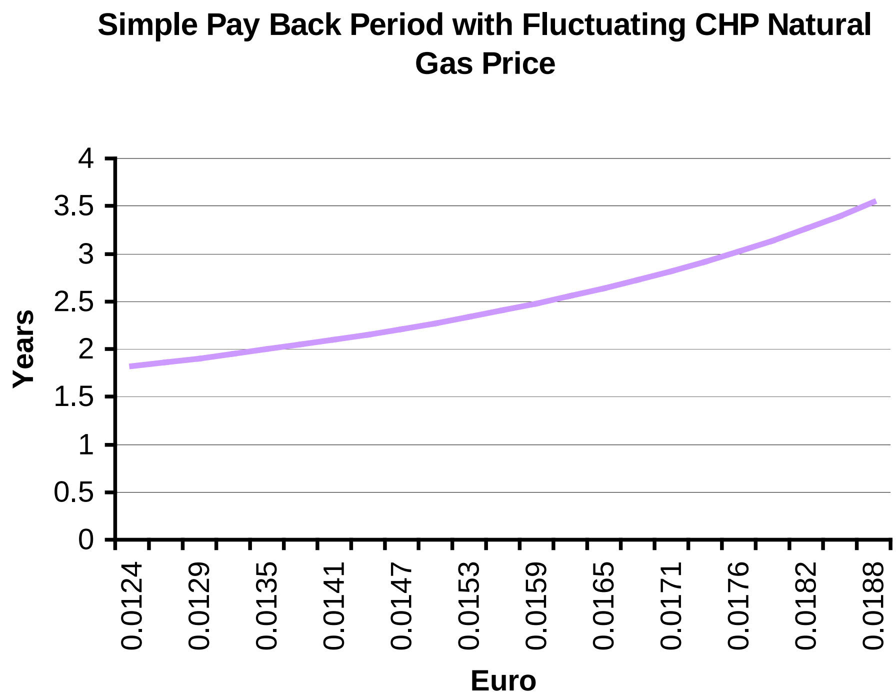
5.4 - SENSITIVITY STUDY RESULTS

In the first segment of this study we have varied the electricity tariff input to see how this will influence the simple pay back period calculation. Below we can see the relevant chart. (The increments are in **0.5** GDr translated to the European currency).



As we would expect, rising electricity tariffs for the Industry, drives the pay back period even lower than the present calculation, and is reaching **1.7 years** for an increase of **8%** (**0.0565**) on the present tariff. This case is a realistic one and could -if it is implemented by the PPC – drive the Industry to choose small-scale CHP systems as a profitable alternative. However, the open market realized through the liberalization process of the energy sector, might drive the price of electricity lower.

The response of the simple pay back period calculation, to changing Natural Gas tariff is charted below. For rising prices the pay back period rises as well in a predictable manner.



It can be seen that the future of small scale CHP is closely connected to the future of natural gas. Doubling the very low natural gas tariff would drive the pay back period towards the four years and therefore would render such projects unprofitable.

6.0 - CONCLUSION

Large scale CHP for district heating has a long tradition. However, small-scale cogeneration units have not been used in most countries before the early nineties. Small-scale cogeneration has proven to offer solutions for a broad range of applications. However, in most European countries very few units have been installed for industrial purposes thus far. This is due to a mixture of legislative, economic and technical barriers.

The share of CHP electricity production in Greece is about **3,4%,** one of the lowest in the European Union.

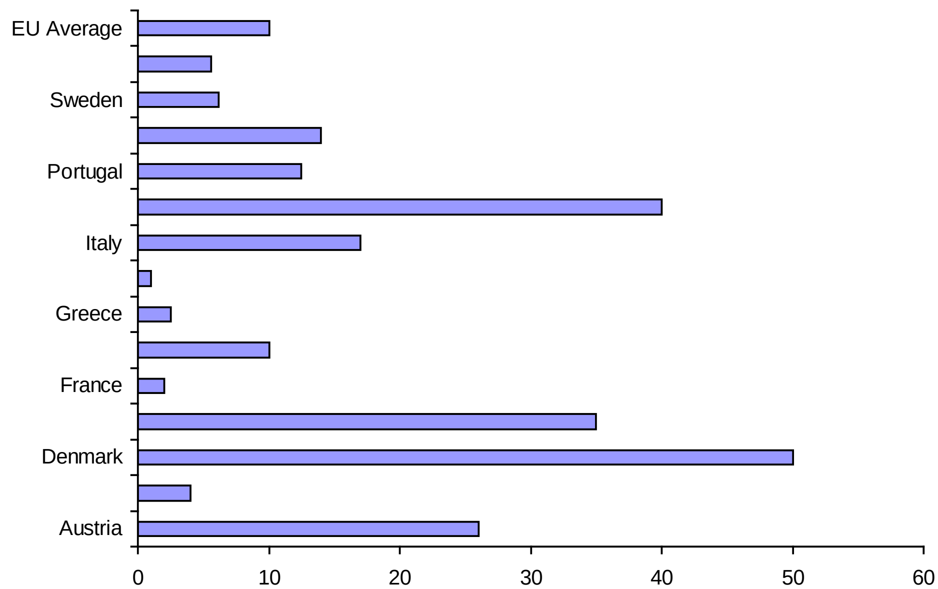


Fig. 13: Presence of CHP in the European Countries (source: Cogen Europe)

The case study has conclusively shown that small-scale cogeneration is an economically attractive option for Industries that want to replace old boiler equipment. However, CHP in Greece is developing slowly due to several reasons:

- Warm climate.
- Low Industrial base.
- Lack of technical know-how and skepticism towards new technologies.
- The bureaucratic procedures for installing and operating cogeneration systems are complicated.
- The existence of a monopolistic electricity utility up to **2001**, the Public Power Corporation, which was not fully supportive of CHP in the previous years.

Like Greece, most countries support cogeneration with forcing the net operator to purchase co-generated electricity and some kind of compensation model. Furthermore, there is investment cost support schemes in most countries. Nevertheless, there are hardly any targets and only few support mechanisms especially for small scale CHP. Sometimes regulations even rule out small scale CHP by encouraging centralized CHP solutions. Unlike most countries, the Greek natural gas provider (DEPA) promotes fuels for cogeneration, which increases the profitability of CHP units remarkably. However, the structure of the Greek energy sector with its vertically integrated energy company, providing low prices for electricity produced in big power plants, is far from beneficial for small scale CHP.

Given the high investment costs per kW installed capacity, in many countries small scale CHP is not considered profitable under the existing legislative frame conditions.

6.1 - FUTURE PERSPECTIVES

Small scale CHP should be considered as a cost-effective solution for replacing of outdated and frequently oversized big-scale heat and power plants. Existing support measures and technical know-how must be communicated to potential users. Potential users often present a lack of know-how concerning promotion schemes and technology. Therefore, in most countries, small scale CHP needs further promotion on the legislative level with special regulations and schemes for small appliances. Measures like green taxes and cogeneration certificates could increase CHP penetration. Such measures in Greece are yet to be implemented.

Natural gas is the most technically and financially appropriate fuel for CHP projects and this trend is going to be maximized in Greece, where the Government encourages the penetration of gas, in order to reach national environmental and security of supply targets. The main problem is that, due to the isolation of Greece from other EU States and the difficult international relations with neighboring countries, gas sources are scarce and the supply of gas for power generation tight.

Although the interest for small-scale cogeneration in the Greek industry is at present rather weak, the ever-changing scene in the legislative, technical and promotional sectors have the potential to strengthen its presence. The environmental benefits and economic viability of this technology have been proven, and it is now in the hands of the European Commission and the national Energy Authorities to further support small-scale cogeneration.

APPENDIX A

HEATING DEMAND PROFILE

Date	Total hot water demand kWh	Hours per Month	Hot water demand kW	Hot water produced by CHP	Top Up heat from boilers kW	Rejected Heat kW
Jan	449689	528	852	862	0	-10
Feb	407237	528	771	862	0	-91
Mar	407329	528	771	862	0	-91
Apr	281446	408	690	862	0	-172
May	413367	528	783	862	0	-79
Jun	259463	528	491	862	0	-371
Jul	529814	528	1003	862	141	0
Aug	137141	168	816	862	0	-46
Sep	433632	528	821	862	0	-41
Oct	559105	528	1059	862	197	0
Nov	598109	528	1133	862	271	0
Dec	360548	408	884	862	22	0

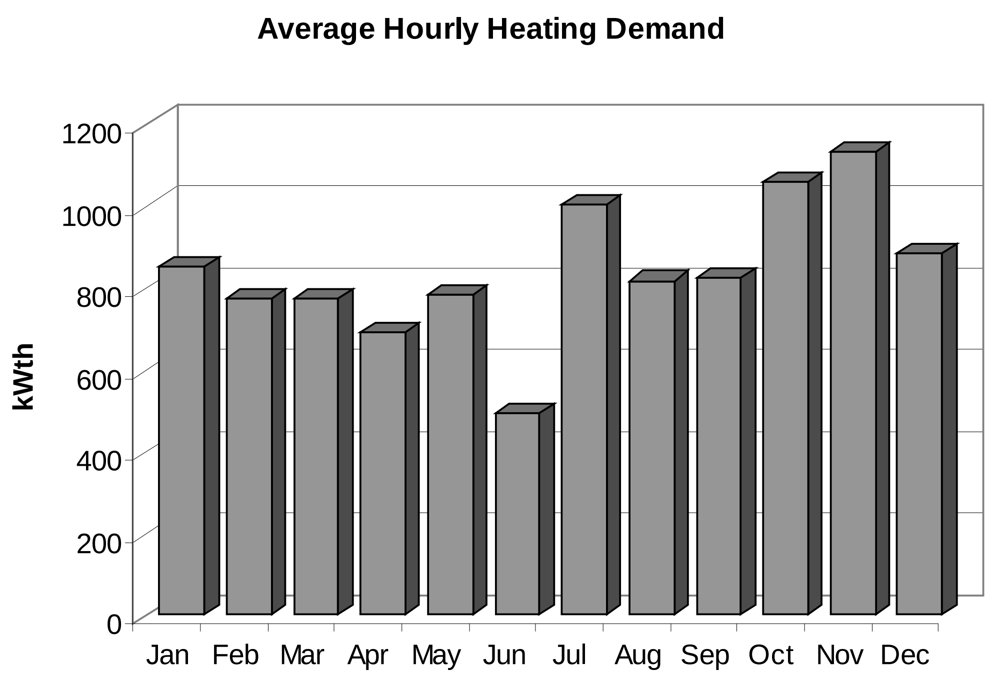


Chart A

ELECTRICAL DEMAND PROFILE

Date	Total Demand kWh	Hours per Month	Hourly Average Demand kW	CHP Electrical Output kW
Jan	702000	528	1330	600
Feb	822000	528	1557	600
Mar	771000	528	1460	600
Apr	732000	408	1794	600
May	705000	528	1335	600
Jun	786000	528	1489	600
Jul	693000	528	1313	600
Aug	588000	168	3501	600
Sep	669000	528	1267	600
Oct	945000	528	1790	600
Nov	1041000	528	1972	600
Dec	849000	408	2081	600

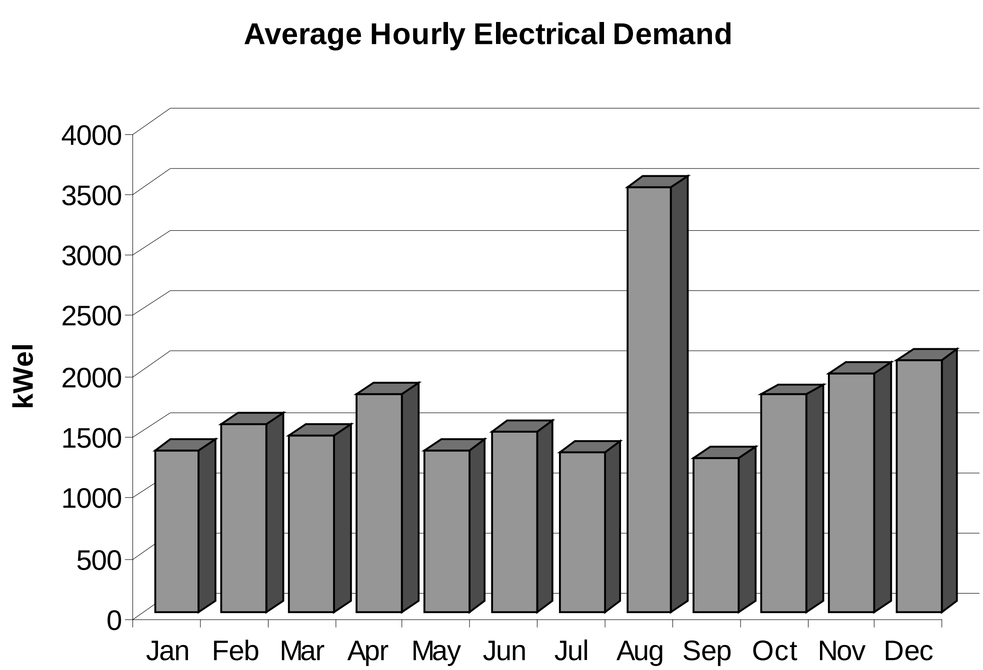


Chart B

CONTRIBUTION OF PROPOSED CHP UNIT

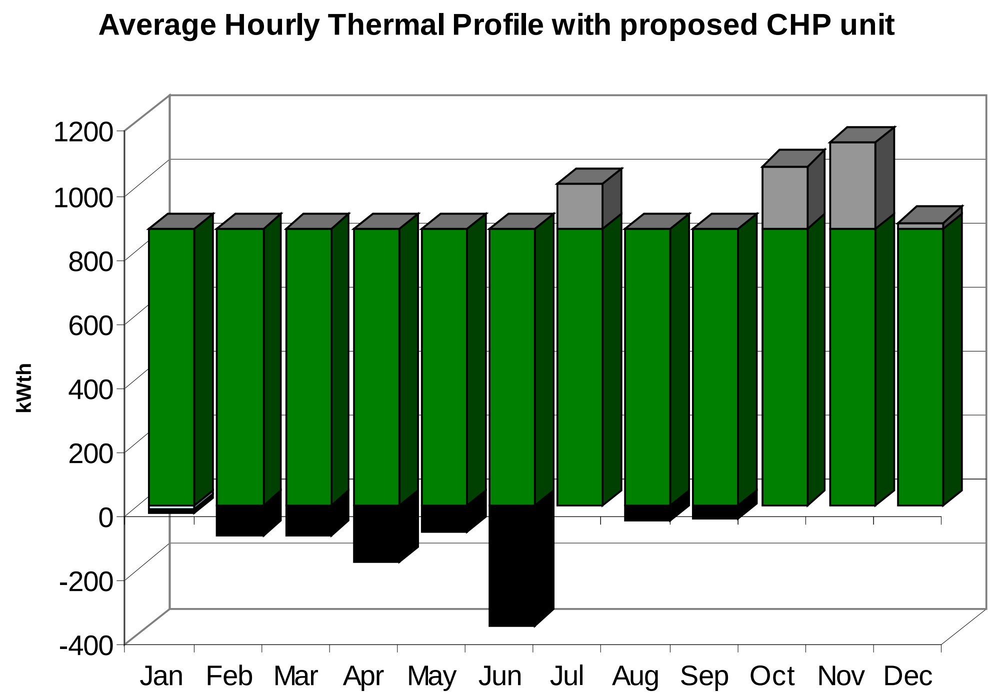


Chart C

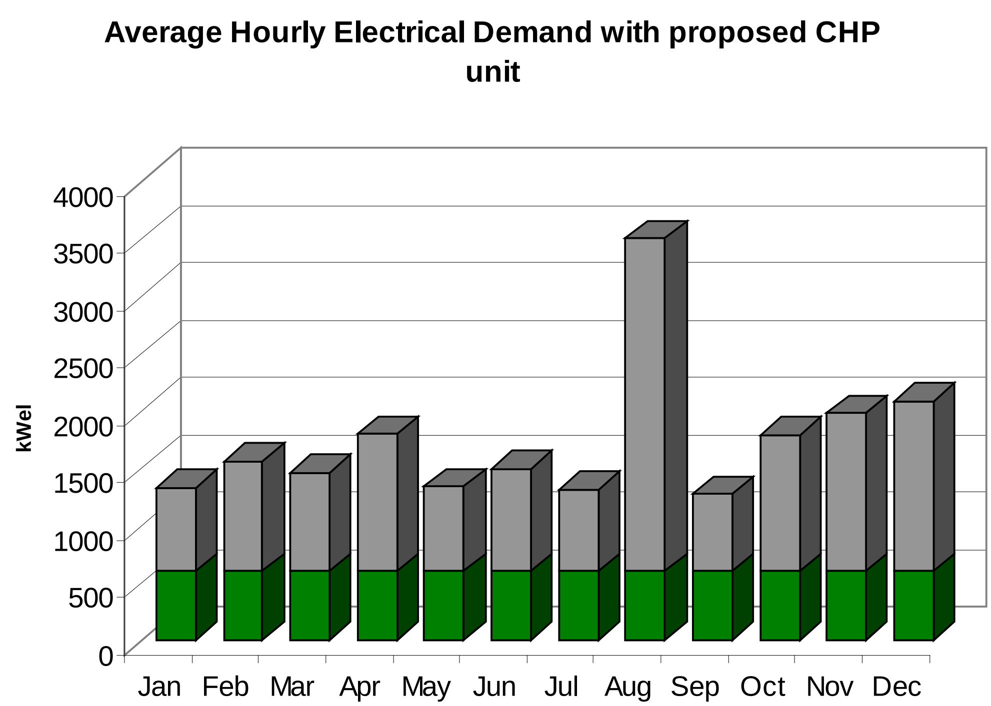


Chart D

PROPOSED CHP UNIT

After considering the energy demand profiles for the factory and with the view of satisfying the thermal demand as fully as possible, the proposed CHP unit for which the calculations are true, was chosen to be a cogeneration unit of **600 kWe** of **NEDALO U.K**. based on a PERKINS engine, which is available in the Greek market for industrial applications from TEMA S.A. The unit's cost comes to approximately **338.000 Euro** with an additional maintenance cost of approximately **18.000 Euro** per annum.

Information on equipment technical specifications and the deduced fuel price for cogeneration, were kindly provided by TEMA S.A., an Engineering and Trading company in the field of Natural Gas.

The figures used for the energy requirements of the factory are true for the year **1998**.

Pay Back Period Calculations

Operational Data

Maximum hours	Day	17	hours
	Night	7	hours
Annual Operating Hours		5.736	hours
Guaranteed Availability		90	%
Average Electricity produced by CHP		600	kWh
Average Heat produced by CHP		862	kWh

Energy Data

CHP Electrical Output	600	kWel
CHP Thermal Output	862	kWth
Gas Consumption	1.758	kW
Gas Price	0,0101	Euro/kWh
Electricity Price during Day	0,052	Euro/kWh
Electricity Price during Night	0,052	Euro/kWh
Boiler Efficiency	80	%

Equivalent cost of energy produced by CHP

	kW		Euro / kWh		Guaranteed annual availability in hours		Annual Costs in Euro
Electricity Day	600	x	0,052	X	3.657	=	114.098
Electricity Night	600	x	0,052	X	1.506	=	46.987
Heating Costs by natural gas boiler*	862	x	0,0141	x	5.162	=	62.739
Equivalent Cost of Energy						=	223.824

* Calculated with boiler efficiency of 80%

Cost of energy with CHP installed

	kW		Euro/kWh		Guaranteed Annual Availability in hours		Annual Costs in Euro
Gas Input	1758	x	0.0101	x	5.162	=	91.655
Maintenance							17.650
Total Cost						=	109.300

Net Total Savings per Annum	114.521	Euro
Total Project Cost	338.235	Euro
Support scheme at 35% of Capital Cost	118.382	Euro

Hence,

Simple Pay Back Period	**1.91**	**years**

APPENDIX B

DEFINITIONS

- *Cogeneration* the simultaneous generation in one process of thermal energy and electrical and/or mechanical energy;
- *useful heat* heat produced in a cogeneration process to satisfy an economically justifiable demand for heat or cooling;
- *economically justifiable demand* the demand that does not exceed the needs for heat or cooling and which would otherwise be satisfied at market conditions by energy generation processes other than cogeneration;
- *electricity from cogeneration* electricity generated in a process linked to the production of useful heat.
- *back-up electricity* the electricity supplied through the electricity grid whenever the cogeneration process is disrupted, including maintenance periods, or out of order.
- *top-up electricity* the electricity supplied through the electricity grid in cases where the electricity demand is greater than the electrical output of the cogeneration process;
- *overall efficiency* the annual sum of electricity and mechanical energy production and useful heat output divided by the fuel input used for heat produced in a cogeneration process and gross electricity and mechanical energy production;

- *efficiency reference value for separate production* efficiency of the alternative separate productions of heat and electricity that the cogeneration process is intended to substitute;

- *power to heat ratio* the ratio between electricity from cogeneration and useful heat when operating in full cogeneration mode using operational data of the specific unit;

- *cogeneration unit* a unit that can operate in cogeneration mode;

- *trigeneration* the simultaneous production of mechanical power (electricity), heat and cooling from a single fuel.

- *micro-cogeneration unit* a cogeneration unit with a maximum capacity below 50 kWe.

- *small scale cogeneration* cogeneration units with an installed capacity below 1 MWe.

- *cogeneration production* the sum of electricity and mechanical energy and useful heat from cogeneration.

- *Green taxes* taxes that are levied on fossil fuels. An example of green taxes is the CO2 tax, which in countries like Norway is designed as a product tax i.e. the tax-base is litre, kg or Sm3, not per ton emission.

- *Cogeneration certificates* certificates that award the use of cogeneration systems. There are different approaches to issuing of green certificates such as the minimum efficiency approach in which all non-condensing electricity produced by the CHP plant is certified, but certificates are only awarded to plant over a certain efficiency threshold, and the substitution approach in which Certificates are awarded for energy savings (or CO_2 savings) relative to reference energy systems[8].

[8] Environmental Finance Magazine

APPENDIX C

thermal

449689	528	851.6837	852	862	10	Jan	0	-10
407237	528	771.2822	771	862	91	Feb	0	-91
407329	528	771.4564	771	862	91	Mar	0	-91
281446	408	689.8186	690	862	172	Apr	0	-172
413367	528	782.892	783	862	79	May	0	-79
259463	528	491.4072	491	862	371	Jun	0	-371
529814	528	1003.436	1003	862	-141	Jul	141	0
137141	168	816.3155	816	862	46	Aug	0	-46
433632	528	821.2727	821	862	41	Sep	0	-41
559105	528	1058.911	1059	862	-197	Oct	197	0
598109	528	1132.782	1133	862	-271	Nov	271	0
360548	408	883.6961	884	862	-22	Dec	22	0

electrical

702000	528	1330	600	730	Jan
822000	528	1557	600	957	Feb
771000	528	1460	600	860	Mar
732000	408	1794	600	1194	Apr
705000	528	1335	600	735	May
786000	528	1489	600	889	Jun
693000	528	1313	600	713	Jul
588000	168	3501	600	2901	Aug
669000	528	1267	600	667	Sep
945000	528	1790	600	1190	Oct
1041000	528	1972	600	1372	Nov
849000	408	2081	600	1481	Dec

Total Project Cost
338235
35% Grant
118382
Resultant Cost for Company
219853

CHP NATURAL GAS PRICE in Euro			Annual CHP Gas Input	CHP Annual Costs in E	Annual Maintenance F	CUP Annual costs (wit	Equivalent Cost of Ene	Net total Savings per A	Project Cost with Stat	Simple Pay Back Period for fluctuating nat gas price
3.2	340	**0.009412**	9074796	85409.84	17650	103059.8	223824	120764.2	219853	**1.820515**
3.3	340	**0.009706**	9074796	88078.9	17650	105728.9	223824	118095.1	219853	**1.861661**
3.4	340	**0.01**	9074796	90747.96	17650	108398	223824	115426	219853	**1.904709**
3.5	340	**0.010294**	9074796	93417.02	17650	111067	223824	112757	219853	**1.949795**
3.6	340	**0.010588**	9074796	96086.08	17650	113736.1	223824	110087.9	219853	**1.997067**
3.7	340	**0.010882**	9074796	98755.13	17650	116405.1	223824	107418.9	219853	**2.046689**
3.8	340	**0.011176**	9074796	101424.2	17650	119074.2	223824	104749.8	219853	**2.098839**
3.9	340	**0.011471**	9074796	104093.2	17650	121743.2	223824	102080.8	219853	**2.153717**
4	340	**0.011765**	9074796	106762.3	17650	124412.3	223824	99411.69	219853	**2.211541**
4.1	340	**0.012059**	9074796	109431.4	17650	127081.4	223824	96742.64	219853	**2.272555**
4.2	340	**0.012353**	9074796	112100.4	17650	129750.4	223824	94073.58	219853	**2.337032**
4.3	340	**0.012647**	9074796	114769.5	17650	132419.5	223824	91404.52	219853	**2.405275**
4.4	340	**0.012941**	9074796	117438.5	17650	135088.5	223824	88735.46	219853	**2.477623**
4.5	340	**0.013235**	9074796	120107.6	17650	137757.6	223824	86066.41	219853	**2.554458**
4.6	340	**0.013529**	9074796	122776.7	17650	140426.7	223824	83397.35	219853	**2.636211**
4.7	340	**0.013824**	9074796	125445.7	17650	143095.7	223824	80728.29	219853	**2.72337**
4.8	340	**0.014118**	9074796	128114.8	17650	145764.8	223824	78059.23	219853	**2.816489**
4.9	340	**0.014412**	9074796	130783.8	17650	148433.8	223824	75390.18	219853	**2.916202**
5	340	**0.014706**	9074796	133452.9	17650	151102.9	223824	72721.12	219853	**3.023235**
5.1	340	**0.015**	9074796	136121.9	17650	153771.9	223824	70052.06	219853	**3.138423**
5.2	340	**0.015294**	9074796	138791	17650	156441	223824	67383	219853	**3.262737**
5.3	340	**0.015588**	9074796	141460.1	17650	159110.1	223824	64713.94	219853	**3.397306**
5.4	340	**0.015882**	9074796	144129.1	17650	161779.1	223824	62044.89	219853	**3.543451**

ELECTRICITY PRICE in Euro			Guaranteed hours of a	Annual electricity cost	Heating Costs by natur	Equivalent Cost of Ene	Cost of energy with CH	Net Total Savings per	Project Cost	Simple Pay Back Period With Fluctuating Electricity Price
17	340	**0.05**	3097800	154890	62739	217629	109300	108329	219853	**2.029493**
17.1	340	**0.050294**	3097800	155801.1	62739	218540.1	109300	109240.1	219853	**2.012566**
17.2	340	**0.050588**	3097800	156712.2	62739	219451.2	109300	110151.2	219853	**1.99592**
17.3	340	**0.050882**	3097800	157623.4	62739	220362.4	109300	111062.4	219853	**1.979546**
17.4	340	**0.051176**	3097800	158534.5	62739	221273.5	109300	111973.5	219853	**1.963438**
17.5	340	**0.051471**	3097800	159445.6	62739	222184.6	109300	112884.6	219853	**1.947591**
17.6	340	**0.051765**	3097800	160356.7	62739	223095.7	109300	113795.7	219853	**1.931997**
17.7	340	**0.052059**	3097800	161267.8	62739	224006.8	109300	114706.8	219853	**1.916651**
17.8	340	**0.052353**	3097800	162178.9	62739	224917.9	109300	115617.9	219853	**1.901547**
17.9	340	**0.052647**	3097800	163090.1	62739	225829.1	109300	116529.1	219853	**1.88668**
18	340	**0.052941**	3097800	164001.2	62739	226740.2	109300	117440.2	219853	**1.872042**
18.1	340	**0.053235**	3097800	164912.3	62739	227651.3	109300	118351.3	219853	**1.857631**
18.2	340	**0.053529**	3097800	165823.4	62739	228562.4	109300	119262.4	219853	**1.843439**
18.3	340	**0.053824**	3097800	166734.5	62739	229473.5	109300	120173.5	219853	**1.829463**
18.4	340	**0.054118**	3097800	167645.6	62739	230384.6	109300	121084.6	219853	**1.815697**
18.5	340	**0.054412**	3097800	168556.8	62739	231295.8	109300	121995.8	219853	**1.802136**
18.6	340	**0.054706**	3097800	169467.9	62739	232206.9	109300	122906.9	219853	**1.788777**
18.7	340	**0.055**	3097800	170379	62739	233118	109300	123818	219853	**1.775614**
18.8	340	**0.055294**	3097800	171290.1	62739	234029.1	109300	124729.1	219853	**1.762644**
18.9	340	**0.055588**	3097800	172201.2	62739	234940.2	109300	125640.2	219853	**1.749861**
19	340	**0.055882**	3097800	173112.4	62739	235851.4	109300	126551.4	219853	**1.737263**
19.1	340	**0.056176**	3097800	174023.5	62739	236762.5	109300	127462.5	219853	**1.724845**
19.2	340	**0.056471**	3097800	174934.6	62739	237673.6	109300	128373.6	219853	**1.712603**

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