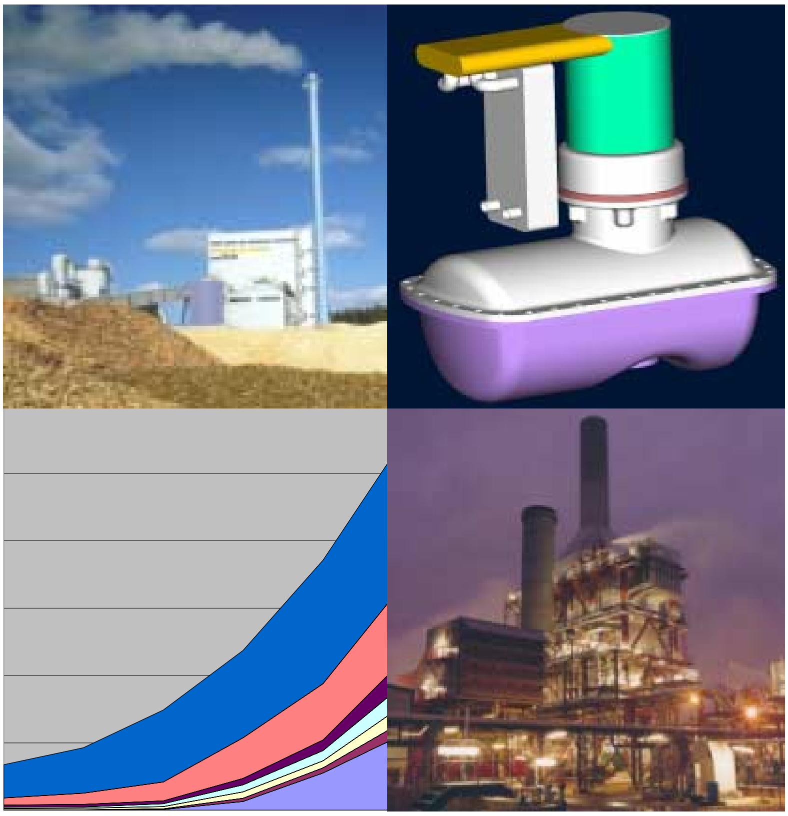
The Future of CHP in the European Market - The European Cogeneration Study



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SUMMARY

Climate change and carbon emissions reduction is an increasingly dominant factor in cogeneration's future. This occurs against a background of liberalising energy markets that have reversed the fortunes of cogeneration in Europe over the past few years. Cogeneration has moved from a period of rapid growth to a sector that is fighting for its survival in most European countries. Over capacity in electricity generation has led to intensified competition and falling electricity prices, which has virtually stopped cogeneration in its tracks in most European countries. For example, in the Netherlands and Germany, cogeneration investments have been suspended and plant even decommissioned as cogeneration struggles to compete against power prices as low as a third of pre-market liberalisation levels.

A dilemma has emerged. While Europe leads the way in environmental action, and promoting the use of the marketplace to achieve environmental objectives, it has also created competition in the electricity sector that fails to value the environmental benefits of cogeneration. The Kyoto mechanisms, particularly emissions trading and Joint Implementation, can considerably improve the long-term competitive advantages of the cogeneration industry, perhaps more effectively and sustainably than direct government support. ***future* cogen** supports the conclusion that the future of cogeneration in Europe is directly linked to the implementation of the Kyoto Protocol flexible mechanisms.

Cogeneration policy

In its 1997 Communication[1] on the promotion of cogeneration, the European Commission called for a doubling of cogeneration production from 9% to 18% of European electricity generation by 2010. However, this is a non-binding target. COGEN Europe, the European trade association, independently estimates the potential for European cogeneration capacity to be some 40% by the same date. Cogeneration can deliver significant reductions in greenhouse gas emissions, and is one of the most important technologies available for Europe to achieve its Kyoto targets. New micro-scale cogeneration technologies ($<15\ kW_e$) are emerging that stand to revolutionise the European power sector by bringing low-environmental impact generation to the level of individual households. The opportunities for medium and large-scale cogeneration plants in industry and tertiary sectors are also large.

future cogen

These are some of the questions at the heart of the ***future* cogen** project, which has examined the prospects for cogeneration growth in 28 countries across Europe. ***future* cogen** has brought together top industrial and policy partners from all over Europe with the aim of building consensus at industry, national government and EU level. It involves the six key partners and an international network of cogeneration "experts" from each of the 28 countries covered - the EU15, 10 CEE countries and 3 others.

Stakeholder consultation was a major objective of the analysis. This was achieved by holding, between September and December 2000, consultation workshops in the majority of the 28 countries. These workshops created consensus on the assumptions and data entered into the ***future* cogen** modelling process, and verified its conclusions and projections. The workshop attendees represented government, industry, and other interested parties. Following the workshops, the model was re-run and final outputs have been synthesised, to produce the final results of the project.

[1] Document COM (97) 514 final

The potential future for cogeneration was assessed using the SAFIRE[2] model, which was significantly updated so that it could provide the levels of detail required by the project. The SAFIRE cogeneration database was also considerably expanded, with the calculation code being adjusted accordingly. Other amendments were also made to the SAFIRE model in order to make the data gathering process more user friendly.

Within the modelling process, four views of the future were developed. Amongst other policy initiatives, three of these "scenarios" assume ratification of the Kyoto Protocol within the EU and implementation of the region's greenhouse gas emission targets. Only the best case scenario includes full world-wide Kyoto ratification, while the worst case scenario assumes failure of the Protocol, with the whole process delayed by ten years. The four different views of the future are:

- Present Policies - current policies in the energy sector continue, particularly those that affect cogeneration, including changes expected to happen. Energy sector liberalisation in Europe is expected to be complete by 2010. Technological developments will be evolutionary, as opposed to revolutionary.
- Heightened Environmental Awareness - based upon Present Policies, but with additional benefits for "green" technologies. This includes the internalisation of the external benefits of cogeneration through the introduction of a carbon tax and faster technological developments.
- Deregulated Liberalisation - liberalisation of European energy markets continues, but with no incentive for smaller scale decentralised generation capacity. The electricity market is expected to be dominated by only a few centralised generators, who strongly influence electricity prices. The net result is that cogeneration could become non-competitive, with plant being closed, leading to a reduction in cogeneration output. This is the worst case scenario.
- In a Post-Kyoto world, the benefits of cogeneration are fully internalised into the cost of the technology. Micro cogeneration becomes technically and economically feasible and fuel cell cogeneration becomes a possibility with the increased amount of investment flowing into "cleaner" technologies in a world tied to the Kyoto Protocol targets. The flexible mechanisms, such as emissions trading and Joint Implementation, provide a new source of finance for cogeneration. Economic and energy policies are focused on decentralised generation and Europe achieves major environmental benefits as a result of the increased efficiency of its generation mix. This is the best case scenario.

What does this mean for cogeneration?

There are a number of conclusions that arise from ***future*** **cogen**, that are both positive and negative. At the current time, negative sentiment dominates the cogeneration market, which is causing major concern in the industry and is directly affecting for cogeneration in the short term and potentially causing significant damage to the confidence of the whole industry.

The medium term future of cogeneration in Europe is at a crossroads. The situation either looks very positive (Post Kyoto scenario), or in the worst case (Deregulated Liberalisation), it may remain static for the next twenty years.

Figure 1 shows the potential for cogeneration in 28 European countries to the year 2020. Regarding the European Union, it is only under the Post Kyoto scenario that significant growth occurs and that the target set by the European Commission is achieved. Alternatively, a continuation of the current status quo is unlikely to lead to much, if any, growth over the same period.

[2] Strategic Assessment Framework for the Implementation of Rational Energy, partially financed by the European Commission

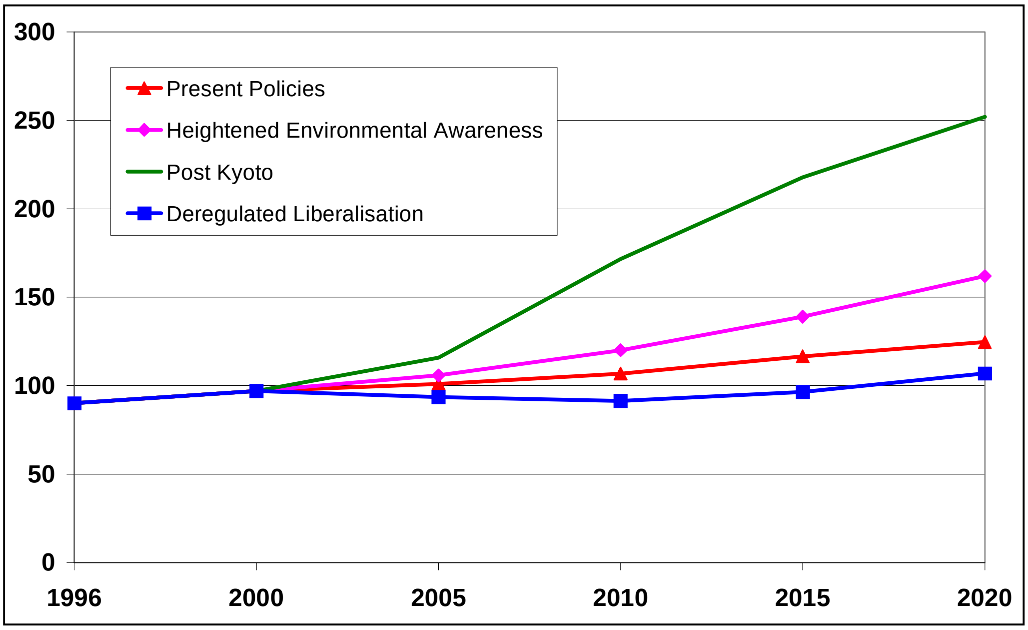


Figure 1 - European cogeneration capacity - 28 countries (GW_e)

Under the Post Kyoto scenario, cogeneration is projected, from the year 2000, to have the potential to:

- almost double total capacity in the EU (74 GW_e to 135 GW_e) by 2010, and to almost triple capacity by 2020 (195 GW_e)
- supply 22% of generated electricity in the EU by 2020[3]
- to increase capacity by 50% in the CEE by 2010 (22 GW_e to 38 GW_e) and to double by 2020 (54 GW_e)
- save 127 million tonnes of CO_2 emissions in the EU by 2010 and 268 million tonnes by 2020
- save 97 million tonnes of CO_2 emissions in the CEE by 2010 and 195 million tonnes by 2020
- install 11 GW_e of biomass cogeneration in the EU by 2010, with an additional 8 GW_e by 2020
- micro-cogeneration can achieve major benefits for cogeneration and the environment, providing up to 30% of all new capacity in the next twenty years. However, this can only be achieved with changes in energy markets and infrastructure
- even under the best case scenario, EU non-domestic cogeneration production is unlikely to surpass 18% of total electricity generation. Any additional growth requires the creation of new cogeneration markets such as micro cogeneration

[3] Electricity generation forecasts taken from European Union Energy Outlook to 2020, Shared Analysis Project, November 1999, Conventional Wisdom scenario

However, there are a number of regulatory and economic factors that are threatening the medium term development of cogeneration. These include:

- investment risk is a major threat to cogeneration in Europe
- uncertainty is currently dominating the cogeneration industry, caused by both market signals and the lack of a legislative and regulatory framework
- in the worst case scenario, lack of investment in cogeneration would lead to neutral CO_2 emissions savings
- insufficient information is being given to the cogeneration industry on future policies, etc, leading to pessimism and negative attitudes
- cogeneration economics is very sensitive to gas prices

A cogen future?

The conclusions from the ***future* cogen** project suggest that climate change policy is the key driver that can overcome the other barriers currently facing the cogeneration industry today, while also enabling cogeneration to compete on equal terms with other sources of electricity and heat supply. The Kyoto mechanisms will help the internalisation of the external costs on energy generation, which will provide the market advantages that clean and efficient technologies need. Other short-term factors include the process of electricity and gas liberalisation in the EU and subsequently the CEE countries. Liberalisation can support cogeneration, but only if the liberalisation process is regulated. For the CEE countries, EU accession is also directly affecting energy policy and the potential for cogeneration

At the current time, negative factors are dominating the cogeneration market which are causing major concern in the industry. This is affecting the potential for cogeneration in the short term and potentially causing significant damage to the confidence of the whole industry.

At the beginning of the project, the team expected to see significant cogeneration growth in both of the positive scenarios (Post Kyoto, Heightened Environmental Awareness). However, primarily owing to the feedback from the workshops and the negative feelings in the cogeneration industry, the future potential for cogeneration is much lower then originally expected.

There is a single primary factor affecting this projected potential; the assessment of risk. In pure economic terms and under current policy frameworks, cogeneration is becoming a marginal technology. Whilst the technology risk is very low, the economic risks are increasing. Competition from marginally-priced electricity supply, increasing fuel prices and the general lack of co-ordinated cogeneration support policies, leads to an overall perception of risk which creates uncertainty and undermines confidence. If such risks could be minimised in the medium to long term, cogeneration would become a technology of choice and would achieve significant penetration. However, the achievement of this future for the industry requires that the barriers to this growth are broken down and replaced with the correct market-based incentive mechanisms.

What can be done?

A number of clear recommendations arise from ***future* cogen**, with the primary aim of minimising the risk associated with cogeneration investment. The correct signals need to be given to the cogeneration industry and market. To achieve this aim, national and international policy makers can do the following:

- Ratify the Kyoto Protocol (helping to internalise the external costs of energy production)
- Send a clear and consistent message on regulatory intentions and developments (e.g. on security of supply). None of the other recommendations will work effectively if this one is not fulfilled
- Establish legislation directly aimed at cogeneration (e.g. a cogeneration Directive), which might, for example, address planning issues and embed cogeneration as the technology of choice over electricity or heat generation, even at a small scale, and to place an obligation on suppliers to purchase a proportion of their supply from cogeneration
- Give energy market regulators the duty to encourage growth in cogeneration (a practical measure that is easy to implement by government)
- Eradicate market barriers (e.g. true costing - grid access, use of grid, export pricing)
- Focus on small to medium scale cogeneration, as this area currently involves the most technology risk
- Cut the link between oil and gas prices to reduce market volatility
- Establish a cogeneration certificates market, which will help to internalise the true environmental benefits of cogeneration
- Produce a standardised definition of cogeneration. One proposal is that this should refer to "good quality" cogeneration, similar to the definition used by Eurostat. It should recognise that electricity is more valuable than heat and show the benefits of cogeneration relative to the individual equivalents. The definition may vary for different plant sizes, technologies applications and load factors
- Open up and incentivise new markets, particularly in the domestic sector for micro cogeneration
- Shift the emphasis of electricity supply towards small decentralised markets

If Europe is to meet its climate change targets, then cogeneration has a major part to play in this process. However, this will not happen in a freely (deregulated) liberalised and centralised market. The flexible mechanisms in the Kyoto Protocol could provide the commercial support to cogeneration, but it is only through harmonised policy in Europe and by the industry adapting to these market mechanisms, that this is most likely to happen. ***future*** **cogen** has shown that open market mechanisms will not provide the support cogeneration needs, so both national and regional government can and must play a more active role in promoting cogeneration to help Europe to achieve its emissions reductions' targets. There are significant threats facing the industry today. If these are not surmounted, the potential benefits from cogeneration will be lost in the short to medium term, and capacity and confidence in the industry will be damaged.

1 INTRODUCTION

1.1 OBJECTIVES

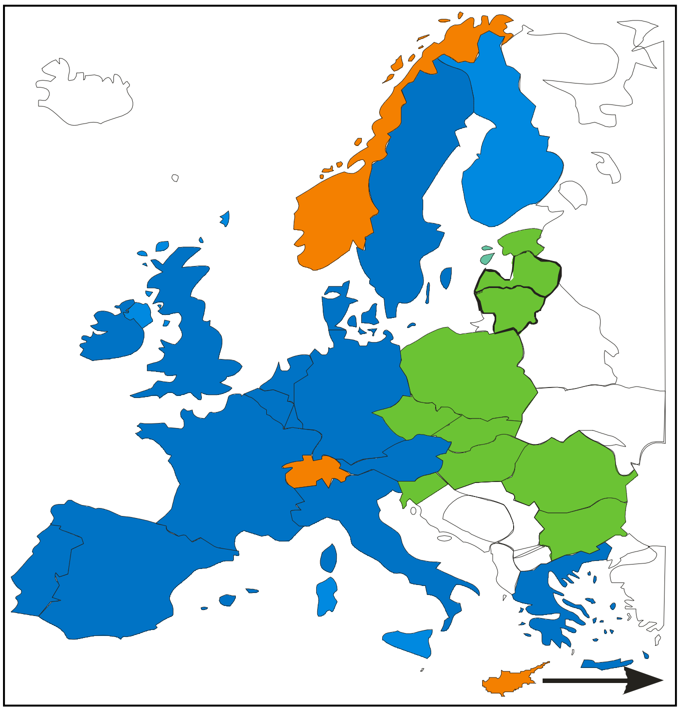
***future* cogen** set out with four principal objectives:

- to assess the current status and future markets for cogeneration in 28 European countries under a range of market scenarios
- to gain broad consensus among key stakeholders on the accuracy of the projections and the practicality and desirability of the options for future cogeneration support
- to determine the effects of energy policy, legislation, taxation, technology development, economic development, energy market liberalisation and other factors on future cogeneration market penetration
- to project the effects of greater cogeneration penetration on the environment

Current and future markets

A primary aim of the ***future* cogen** project is to achieve a standardised approach for the analysis of cogeneration in the major countries of Europe. The scope of the project involved 28 countries, including the 15 countries of the European Union, ten countries of Central and Eastern Europe, and three others (Cyprus, Norway and Switzerland). Figure 1.1 shows the countries covered by the project, colour coded according to the category in which the country is located.

Figure 1.1 - *future* ***cogen*** country coverage



Stakeholder consensus

***future* cogen** is worthless without agreement and consensus from key stakeholders involved in cogeneration in Europe. A group of in-country experts was recruited in each country covered, to enhance the quality, feasibility and acceptability of the ***future* cogen** country outputs and reports. To gain a broad consensus, these experts also created a small forum of national stakeholders to provide their knowledge and expertise to the project. However, information was a two-way process, as the experiences gained in individual countries could be transferred across the whole of Europe, thereby improving the awareness of cogeneration markets and opportunities.

Future market penetration

Through the detailed modelling of cogeneration to 2020, performed by the SAFIRE[4] model, the potential markets for cogeneration have been calculated for all 28 countries in ***future* cogen**.

Environmental effects

A major strength of cogeneration is it environmental benefits, through the highly efficient use of energy. The consequent low emissions per unit output can be used to help Europe meet it emissions targets, as proposed within the Kyoto Protocol. ***future* cogen** has assessed the environmental benefits of increased cogeneration penetration for CO_2 emissions and the potential benefit to Europe in achieving it emissions reduction targets.

1.2 WHAT IS COGENERATION?

The first task of ***future* cogen** was to define the term "cogeneration". The experience from international consultation is that there are several different definitions of cogeneration in Europe, ranging from the simple to the complex. These definitions should be harmonised into a coherent and agreed system that can be accepted by the whole region. But before this, the relevant issues must be addressed.

1.2.1 Defining Cogeneration

Cogeneration is the simultaneous generation of usable heat and power (usually electricity) in a single process. Useful outputs can be more varied: increasingly, heat is being used to drive absorption chilling, and in some cases power can be mechanical power, for example to drive a compressor. The term cogeneration is synonymous with combined heat and power (CHP), which is terms often also used on an international basis. Cogeneration uses a variety of fuels and technologies across a wide range of sites, and scheme sizes. The basic elements of a cogeneration plant comprise one or more prime movers (a reciprocating engine, gas turbine, or steam turbine) driving electrical generators, or other machinery, where the steam or hot water generated in the process is utilised via suitable heat recovery equipment for use either in industrial processes, or in community heating and space heating.

Whereas an electricity-only plant is typically large, and connected at very high voltage to the grid transmission system, a cogeneration plant is typically much smaller, attached to a site which consumes the heat and power produced (or a large proportion of it), is sized to make use of the available heat, and connected to the lower voltage distribution system (i.e. embedded). Not only is cogeneration more efficient through utilisation of heat, it also avoids significant transmission and distribution losses, and can provide important network services such as black start, improvements to power quality, and the ability to continue to supply the site if the grid goes down.

Cogeneration usually displaces boiler plant and electricity-only plant using a range of fuels and technologies. Cogeneration typically achieves a 25% to 35% reduction in primary energy usage compared with electricity-only generation and heat-only boilers. This can allow the host organisation to make substantial savings in costs and emissions where there is a suitable heat load.

[4] Strategic Assessment Framework for the Implementation of Rational Energy, originally developed by ESD with support from the European Commission (DG Research), but since used in numerous applications

1.2.2 Good Quality Cogeneration

Any scheme that generates power and recovers heat for useful supply can be called cogeneration. Some cogeneration schemes are essentially very large boilers with a small amount of power generation, whilst some are large power stations with little more than a steam leak. Either types of plant would make little savings in relation to alternative conventional heat-only boilers and power-only generation. Good Quality Cogeneration is best described as that which makes significant savings in relation to conventional alternative heat-only and electricity-only plant. The savings from cogeneration are optimised by achieving the highest electrical efficiency, whilst at the same time meeting the heat demands of the host heat customers from the available heat generated in the process.

Many countries have quantitative definitions of cogeneration. One easily accessible and well-defined methodology developed in the UK to determine eligibility for certain fiscal benefits can be found at http://www.chpqa.com. Eurostat is developing a measure for determining EU statistics.

Some schemes are based on a simple efficiency method, and thresholds of 65-70% Gross Calorific Value (equivalent to 70-77% Net Calorific Value) are common. Other schemes recognise that electricity is ‘harder won’ than heat. For example, electrical efficiency, net of transmission and distribution losses is 37% (GCV) in the UK, whereas boiler efficiencies average 75% (GCV). Thus a scheme with 10% electrical efficiency and 60% heat efficiency does not produce the same benefits as one which is 60% electrical efficiency and 10% heat.

Even schemes that may not achieve any threshold criteria for all of their capacity and output will offer environmental benefits over conventional alternatives. In such cases, many methods for determining good quality scale back the capacity, fuel used, or electricity generated, to that which would have been good quality. The remaining portion of the scheme is treated as equivalent electricity-only or heat-only generation.

In any case, a method that is robust, determinate, and able to withstand legal challenge, will need to be agreed (either at the national level, or at the EU level) before cogeneration can receive significant regulatory or fiscal benefit.

It may be possible, over time, to agree a common methodology for determining Quality. However, given the range of applications of cogeneration (for example in community or district heating and in industry), together with the range of fuels, technologies, and market and regulatory frameworks in different countries, it may be that a range of thresholds or factors for heat and power are applicable in different countries.

1.3 KYOTO PROTOCOL

The Kyoto Protocol stipulates that industrialised countries and countries with economies in transition – the group of so-called Annex I countries – shall reduce their overall emissions of carbon dioxide and other five greenhouse gases (GHG) by at least 5% as compared to their 1990 emissions levels[5]. This should be achieved by the first commitment period 2008 to 2012. In order to meet these targets cost effectively, the protocol allows for the use of the market-based Kyoto Mechanisms at an international level. Essentially, these mechanisms should enable Annex I countries to meet part of their reduction objectives by financing GHG emission

[5] To be precise, the emission targets apply to countries listed in Annex B of the Kyoto Protocol instead of Annex I of the Framework Convention on Climate Change. Since the list of Annex B countries is almost identical to the list of Annex I, except for Belarus and Turkey which are not listed in Annex B but in Annex I, this paper does not distinguish between these two and refers only to Annex I.

reductions abroad, where mitigation cost might be lower. The Protocol refers to the following three international forms of climate change mitigation:

- Joint Implementation (JI) between Annex I countries,
- the Clean Development Mechanism (CDM) between Annex I countries and non-Annex I countries, i.e. developing countries,
- International Emissions Trading (IET) between Annex I countries.

IET has been classified as a *cap and trade* system, which starts by defining an aggregate, legally binding emission limit for a group of countries. This overall budget of emission permits is then allocated to eligible participants of the trading system. Afterwards, these permits can be traded amongst the participants. With JI & CDM, classified as *baseline and credit* regimes, the tradable permits are related to emissions reductions achieved by eligible greenhouse gas mitigation projects. This means that host countries are willing to sell off parts of their Kyoto budgets in return for foreign investment in national emission reductions. These reductions are calculated by comparing the actual emissions of a project with the emissions that would have occurred in the absence of the relevant project, i.e. the reference scenario or baseline.

The net effect of such schemes is a move towards the full internalisation of the environmental costs of clean and efficient energy. Cogeneration fits within this category as an efficient technology that leads to the reduction of emissions, so has the potential to benefit significantly from the implementation of the Kyoto Protocol.

1.4 METHODOLOGY

The approach taken for the ***future* cogen** methodology formed a key part of the whole project. Without a robust methodology and without endorsement from national representatives in the countries covered, the results and outputs would have failed to have the same level of validation and consensus. ***future* cogen** focused on the gathering, analysis and production of both qualitative and quantitative data. This required that the structures and procedures performed should achieve the quality outputs desired and expected by the team.

1.4.1 The Data Network Team

The success of ***future* cogen** is dependent upon the input received from the "Data Network" of in-country experts recruited within each of the countries covered. The development of individual country profiles was dependent upon the qualitative and quantitative information provided by these experts, including information on the four modelling 'scenarios' developed during ***future* cogen**. Table 1.1 shows the list of Data Network members that assisted the core team.

Table 1.1 - Data Network members

Country	Data Network partner	Country	Data Network partner
EU15		**CEE**	
Austria	OEKV	Bulgaria	ESD Bulgaria
Belgium	Cogen Europe	Czech Republic	Cogen Czech
Denmark	Danish Energy Agency	Estonia	Estonia Power and Heat Association
Finland	VTT Energy	Hungary	Magyar Kapcsolt Energia Tarsasag
France	ATEE	Latvia	Strasa Consulting SIA
Germany	Bundesverband Kraft-Wärme-Kopplung e.V.	Lithuania	Lithuanian Energy Institute
Greece	HACHP	Poland	KAPE S.A.
Ireland	Irish Energy Centre	Romania	ENERO
Italy	Ecuba	Slovak Republic	Slovak Energy Inspection Agency
Luxembourg	Luxcontrol	Slovenia	Institut Jozef Stefan
The Netherlands	Cogen Nederland		
Portugal	Cogen Portugal	**Other**	
Spain	AESA	Cyprus	Environmental Energy Ltd
Sweden	KanEnergi	Norway	KanEnergi AS
United Kingdom	ETSU	Switzerland	E4Tech

1.4.2 Consultative Group

The Consultative Group was formed from experts in each of the 28 countries covered by ***future* cogen**. The Consultative Groups were particularly active in the countries where consultation workshops were held, as they had the opportunity to be actively involved in the outputs of the project and to attend the presentation of results for their own country. The Consultative Group members covered three main areas of expertise:

- Government
- Cogeneration industry
- Other interested parties

Government includes people, where relevant, who are responsible for cogeneration in the ministries of Energy, Environment, Economy and Industry. The **cogeneration industry** list includes manufacturers and suppliers of cogeneration equipment, energy utilities, developers of cogeneration schemes, consultants to the cogeneration industry, ESCO's, etc. The final section of the Consultative Group, **other interested parties**, includes energy agencies, regulatory bodies, non-government organisations (NGOs), pressure groups, etc. Table 4.3 shows the number of attendees at each consultation workshop.

Consultation

In order to obtain consensus for the country outputs, experts in the majority of the ***future* cogen** countries were consulted in addition to the primary Data Network inputs. The primary activity was through a number of consultation workshops held in the majority of the 28 countries. The size of the consultation group varied from country to country, depending upon a number of factors, including the level of activity in the country, the size of the country and the number of invitees produced by the partner. Table 1.2 shows the number of members in each consultative group. The Consultative Group members do not include the Data Network partners.

Table 1.2 - Number of members in each Consultative Group

Country	No. of members	Country	No. of members
Austria	10	Latvia	10
Belgium	6	Lithuania	26
Bulgaria	14	Luxembourg	3
Cyprus	0	Netherlands	2
Czech Republic	30	*Norway*	0
Denmark	10	Poland	9
Estonia	9	*Portugal*	0
Finland	22	Romania	35
France	0	Slovak Republic	11
Germany	8	Slovenia	7
Greece	3	Spain	11
Hungary	22	*Sweden*	0
Ireland	0	Switzerland	6
Italy	15	United Kingdom	13
Total	149	-	133

Note: Workshops were not held in countries in *italics*

1.4.3 Technology

Cogeneration covers a diverse range of technology, size and fuelling options, each applied within different sectors. The team agreed that to model this matrix fully was too complex and should be simplified. The resulting list is shown in table 1.3. The table shows that the option to specify individual technologies has been excluded, based upon the assumption that at any one time, there will only be a single technology option predominant within each field of the table. For example, the current assumed technology for biomass cogeneration is a steam turbine. However, by 2010, the predominant technology is expected to be gasification or pyrolysis based. Consequently, the relevant capital costs and operational parameters for each technology are specified in the modelling process for each marker year. Further details of these assumptions are specified in section 3 of this report.

Table 1.3 - Cogeneration sector-fuel-size matrix

Sector	Plant size (MW_e)	Natural gas	Coal (& products)	Heavy fuel oil	Light oil (incl. diesel)	Solid biomass	Solid wastes	Biogas
Domestic	< 0.015	*			*		*	*
Commerce	0.015-0.1	*			*	*	*	*
	0.1-1	*			*	*	*	*
	1-5	*	*	*	*	*	*	*
Industry	1-5	*	*	*	*	*	*	*
	5-50	*	*	*	*	*	*	*
	>50	*	*	*	*		*	

1.4.4 Modelling

***future* cogen** has used the outputs from two models for the potential of cogeneration in Europe. These include the SAFIRE model and a separate model focussing on micro-cogeneration.

SAFIRE

SAFIRE (Strategic Assessment Framework for the Implementation of Rational Energy) has been a core component of ***future* cogen**. SAFIRE is a framework for looking at the impacts under different sets of assumptions. It provides a consistent analysis methodology to test different scenarios.[6] The aim of the SAFIRE is to be used to examine and assess the impact of different energy technologies and RTD against a background of different economic instruments and policies. SAFIRE works on a bottom-up basis, competitively matching energy supplies to energy demands. SAFIRE is a database and computer model that assesses the markets for and impacts of new energy technologies against a background of different economic instruments and policies. SAFIRE applies its calculations to both heat and electricity, where the electricity can be either centralised or decentralised.

The model uses data on energy demand, energy resources, technologies and policies from a series of interlinked databases to calculate their impact on these economic indicators. The SAFIRE databases include data for 30 European countries, which were updated for the 28 countries included in the project. Projections can be made for up to 40 years from a user-defined base year.

Within ***future* cogen**, SAFIRE has been extensively updated in order to provide a better reflection of the market for cogeneration. They have achieved a major improvement in the scope of the SAFIRE cogeneration methodology and allow an improved modelling process for the model. The main improvements that have been made to SAFIRE model have been the following:

- inclusion of domestic sector cogeneration into the methodology (district heating is dealt with separately)
- expansion of the sizes of plant available (section 1.4.3)
- expansion of the fuels available for cogeneration
- methodology improvements, particularly for industrial demands, to enable easier data gathering

Data Inputs

The inputs in the modelling process can be divided into two areas:

- Base year data (typically)
- Scenarios

A base year of 1997 was determined at the beginning of ***future* cogen**, as it was deemed to be the most recent year for accurate and comprehensive Europe-wide data regarding cogeneration and the energy sector. However, the team discovered that the quality and quantity of cogeneration statistics in Europe is very variable. Therefore, it was not possible to maintain a standard base year of 1997, so the most recent accurate data for each country was used in the modelling process.

The information requirements of the SAFIRE modelling process includes all relevant data for the energy sector, including the following:

[6] SAFIRE, European Commission, DG XII, EUR 16785 EN, November 1995

- disaggregated heat and electricity demands by sector
- energy demand by fuel
- cogeneration installed capacities
- cogeneration technologies and operating characteristics
- cogeneration costs
- fuel prices

Scenarios are views of the future, defined by specifying a set of policies that affect variables such as discount rate, market penetration curves, taxes and subsidies, or environmental factors, and by defining changes in technology cost and performance. Four scenarios were developed for ***future*** **cogen**, which are specified in detail section 3. The scenarios are:

- Present policies - continuation of current policies, Kyoto is not ratified world wide, no major technology developments are expected, liberalisation is expected to be complete by 2010.
- Heightened environmental awareness - based upon Present Policies, but with additional benefits for 'green' technologies. World wide Kyoto ratification is expected within five years
- Post-Kyoto - best case scenario, in addition to world wide ratification of the Kyoto Protocol, the benefits of cogeneration are fully internalised, micro cogeneration becomes technically and economically feasible and policies are focused on decentralised generation.
- Deregulated liberalisation - worst case scenario, assumes continued liberalisation of European energy markets, but with *no* regulation protecting smaller scale decentralised generation capacity, leading to market domination by a few centralised generators. All Kyoto commitments are expected to be delayed by up to ten years

The parameters included in the scenarios are:

- energy demand changes
- cogeneration technology changes (costs, operating factors)
- policies (taxes, subsidies, buyback opportunities)
- technical parameters (grid connection)
- market characteristics (liberalisation, willingness to invest, market deployment)
- fuel price changes

Micro cogeneration model

In addition to the modelling performed by SAFIRE, micro cogeneration modelling was also performed as part of the general modelling process and as a parity check with the SAFIRE outputs. This model, managed by Sigma Elektroteknisk, has data for the 15 EU countries. This exercise added an extra dimension to the micro-cogeneration modelling, as it enabled the analysis to be performed at a more detailed level, thereby enhancing the results of the project, while also proving support to the outputs from the primary SAFIRE modelling.

2 COGENERATION MARKETS AND TECHNOLOGIES

This section reviews the major issues affecting cogeneration markets and technologies today. Cogeneration has been a success story in the past and this experience must be used if the future is to remain positive. The knowledge gained in individual countries can lead to benefits across the whole of Europe, as cogeneration becomes an ever-increasing generation option in the region. This section is not intended to be a full review, but gives a flavour of current thinking.

2.1 MARKET EXPERIENCE

The market for new cogeneration plant is currently difficult. Liberalisation is being implemented across Europe at different speeds and in different ways. This is leading to confusion and uncertainty in the energy markets and is having a direct effect on cogeneration. However, there are positive market developments in various European countries that have encouraged cogeneration, the experience from which need to be transferred across the whole region. The following sections outline the main sources of markets areas that are currently relevant to cogeneration in Europe.

2.1.1 Liberalisation: The UK Experience

Introduction

Traditionally, energy markets have been characterised by their monopolistic structure. However in the last few years there has been a world wide trend to liberalisation, sometimes with regulation, sometimes hand-in-hand with deregulation. Indeed often, liberalisation and deregulation are mistakenly seen as the same thing. Within Europe, this liberalisation is happening in different forms and to varying degrees. The process has been consolidated by the Electricity and Gas Directives.

The extent of liberalisation and regulation is currently the most important event shaping the future energy market in Europe and it will have crucial impact in the development of cogeneration. In principle liberalisation offers new opportunities. However, new barriers may arise if liberalisation is not properly regulated. The economic viability of the technology is very sensitive to a range of factors, especially electricity and gas prices. With liberalisation new opportunities will arise, but also new barriers. The final result will be determined by the actions that the governments take to address market failures.

Features of a Liberalised Energy Market

Liberalisation does not only mean opening the markets to competition, it rather requires restructuring a number of key elements:

Corporatisation and privatisation

Ideally, ownership of assets should be separated from the regulatory activity of the State. Full privatisation is the preferred option.

Unbundling and sector restructuring

Monopolistic markets tend to be vertically integrated. Liberalisation requires separation of activities that are natural monopolies from those that can be open to competition. Natural monopoly activities include transmission and distribution, while generation and supply should be open to competition. The four types activities should be separated in a truly liberalised market.

Competition

There are three possible models for competition: competitive pool model, grid access model and single buyer model. All the models involve unbundling and clear rules for grid access.

Regulation

Regulatory vigilance of the market is essential to ensure that the market works properly, and not only at initiation, where it is necessary to provide appropriate guidelines to avoid the use of abusive practices and ensure a non-discriminatory and transparent framework. But even once a competitive framework is established, regulation cannot melt away, as many once thought. Markets evolve. And markets can deliver different things including social and environmental objectives.

Liberalisation does not necessarily mean adopting a "*laissez-faire*" approach. Liberalisation and deregulation are two separate themes which are often confused. Because there is a tendency to liberalise does not mean the new market has no rules or so social and environmental objectives. The market has failures (such as social, environment, and ensuring security and diversity of supply) that may need to be addressed through intervention.

Pressures for liberalisation in Europe

This development has been mainly driven by three considerations:

- Energy prices: Monopolistic markets lead to high energy prices (they were 40% in Europe than in the USA or Australia). This had a big influence in the competitiveness.
- Security of supply: With the proper regulation, an open market framework can create the right conditions for long-term investments.
- Environmental concerns: Liberalisation of the energy markets was seen as a way to encourage more efficient utilisation of resources.

The results of this process has been the establishment of a Single European Electricity and Gas Market though two Directives. Both cover the issues mentioned above. Both Directives lead to a minimum partial three steps liberalisation. In general, liberalisation in the Electricity Markets has happened faster and more deeply than was prescribed by the Directive. This is different in the Gas sector, where real price competition does not exist since gas price is linked to oil price.

The commission believes the basic objectives pursued by the internal market (lower prices, increased competitiveness, high standards of public service, security of supply, and environmental protection) are better pursued under conditions of full competition[7]. The rapid completion of the internal market in this area represents, therefore, an important step in meeting the Community's objectives. The adoption of these proposals can be expected to

[7]Commission Communication 2001 (125), completing the internal energy market. The communication includes a proposal for a Directive amending 96/92/EC and 98/30/EC, common rules for the internal markets in electricity and gas.

bring important benefits in terms of competitiveness and employment, and provide competitive prices and higher standards of service to Community citizens for gas and electricity. Whether the directive is sufficient to complete the liberalisation process, and embed the basic objectives above, such as environmental protection, remains to be seen.

Practical effects of the liberalised markets for cogeneration

The Gas Market

In principle liberalisation should lead to falling gas prices, which should be beneficial to cogeneration. A second positive effect would be a greater flexibility in tariff structure. There are however certain risks that the process is not as beneficial as it should be:

- *Limitations in the extent of competition:* The Directive allows the imposition of a minimum consumption threshold to cogeneration, below which competition is not necessary. This could harm the development of small-scale cogeneration, which could not choose supplier. This is unreasonable, given that in some markets, competition applies to all consumers regardless of size, and including domestic customers
- *Limited movement towards economic pricing:* In some countries some type of clients have not been paying for gas at full costs, with implied cross-subsidies between consumers. This is especially the case with domestic consumers. Liberalisation would raise the gas price for them.
- *Links to unrelated markets:* In fact, the evidence since the beginning of liberalisation (according to the Directive 10 August 2000), shows that there is not a real market so far, since gas price is linked to oil price. As a result, gas prices have more than doubled. This situation does not make sense in a liberalised market.

The Electricity Market

The effect of liberalisation on electricity has been to lower prices.

- *Low electricity prices without a corresponding fall in fuel costs* puts pressure on generators, and smaller players whose plant is more dependent on gas compared to other fuels –such as co-generation plants- are particularly exposed. This is a disincentive to invest in cogeneration.
- *Barriers to market entry:* With liberalisation, many of the traditional barriers affecting cogeneration will disappear. However, markets are not fully open in practice and certain barriers may arise from the opening process itself. Others may arise from government actions to protect certain sectors of the economy.
- *Movements towards economic pricing:* The negative effects of competition will not apply when prices have been maintained below economic levels, since electricity prices will then raise as a result of liberalisation.

Regulation

Regulation has two main roles:

- Regulate behaviour of private sector monopolies
- Ensure effective and fair competition in those elements not fully open

The following aspects will have a profound impact on uptake of Cogeneration:

The aim of regulation

The remit of the regulator will have a big influence in the way the regulatory regime is operated. If the regulator shares responsibility for meeting a given Government target (for example a Cogeneration target) for security of supply or environmental reasons, they will be likely to operate the regulatory regime to encourage cogeneration, for example, in the granting of licenses, or the regulation of use of system charges.

At the same time, whilst the Regulator needs to be tied in to Government objectives, they also need a degree of independence from the government and from other market participants, to avoid undue interference and inconsistencies.

The regulation of competition

A focus on the regulation of competition is often an indicator of an immature or emerging regulatory regime. Issues include:

- *Flotation objectives:* In principle, privatisation should establish a business environment rewarding efficiency. In practice, there may be market distortions at least in the short term.
- *Marginal Cost Pricing:* The commercial basis for management of the energy sector will tend to reflect short term marginal costs rather than long term marginal costs, especially in a situation of over capacity as the one Europe faces now. The situation is not sustainable in the long term, but as long as it persists investment in cogeneration will be discouraged.
- *Access to capital markets:* The move towards privatisation will give larger access and flexibility for private funds, therefore improving the possibilities of new investments such as cogeneration. The extent to which this will represent an incentive will depend upon the cost and availability to capital funds. It is necessary to ensure a favourable return of the investment.
- *Development of multi-utilities:* While liberalisation requires unbundling, it has also encouraged utilities to enter into new business (water, telecommunications, electricity, heat, etc.) In principle, this focus could be beneficial to cogeneration, as it provides the opportunity to integrating electricity and heat.

The UK Experience

The continuing role of the regulator

At the outset of Privatisation and Liberalisation in the UK, it was assumed that regulation was about fostering competition where it could, and controlling natural monopolies where competition could not be introduced. It was assumed that the regulators role would wither, and be replaced by normal competition regulation (In the UK this would be the Monopolies and Mergers Commission and the Office of Fair Trading). However, the role of regulation has not withered, but it has fundamentally changed. In the UK, Under the new Utilities Act, Ofgem's (Office of Gas and Electricity Markets) primary regulatory duty will be:

"to protect the interests of consumers, where appropriate by promoting competition. Consumers are defined in terms not only of present but also future consumers of the gas and electricity industries, thus enabling a view to be taken beyond the immediate future. It will be for Ofgem to judge how to interpret this duty, and how to balance it with our other secondary

duties. These include the need to have regard to low income and rural customers and, in relation to the environment, to 'have regard, in carrying out [Ofgem's] functions, to the effect on the environment of activities connected with the generation, transmission, distribution or supply of electricity and the conveyance of gas through pipes'.

This will require Ofgem to strike a careful balance between our primary duty and our secondary duties. In some cases there may be no conflict between our economic, social and environmental responsibilities, for example in creating incentives in the price regulation of transmission and distribution systems which reduce losses of gas and electricity. In other cases there may be a tension which will require choices to be made. The Government will issue social and environmental guidance to Ofgem."
(From Ofgem's Environmental Action Plan, Discussion Paper July 2000, http://www.ofgem.gov.uk/docs/enacplancon.pdf *)*

This will have effect, for example, in the design of the charging and licensing regime, which significantly affects the regime for Cogeneration. The regulatory regime currently assumes remote major power generator separated from the end customer, and a transmission and distribution network in between. This model is increasingly flawed. There are several aspects to this:

- *licensing:* licensing obligations are necessarily more burdensome on small plant, or operators of plant outside a portfolio. They penalise cogeneration.
- *Cost reflective use of system charges:* Costs such as transmission and distribution costs assume that electricity enters the distribution network at the top, and leaves it at the bottom, making use of the whole distribution network. Embedded generation, connected within the network, and exporting small amounts of electricity, use only a very small portion of the network, but have to pay as if they used the entire network. This is an unreasonable cost;
- *Rewards for embedded benefits:* Cogeneration provides benefits such as improvements to power quality and security, and avoidance of grid reinforcement. These benefits are often not recognised.
- *Access to networks*: In theory regulated Third Party Access will provide greater transparency. However, the cost of connection to the network, including the cost of reinforcing back to high voltage networks (or high pressure gas mains) is not transparent (in terms of what exists and how the alterations have been priced). Often the Distribution Network Operator only allows licenses for a small number of contractors to work on its network (and often its own employees). There is limited competition in actually carrying out connections. Thus there is a role for the Regulator is ensuring information provision, a predictable pricing structure, approved licensing and competition arrangements.
- *Market restructuring:* Safeguard measures are necessary to ensure effective unbundling of generation, transmission, distribution and supply (and of upstream and downstream operations for natural gas). Particularly important for cogeneration is to ensure separation of distribution and supply activities. Otherwise the distribution company will have a commercial interest in imposing a number of barriers to distribution network access.
- *Development of energy services companies,* including selling of products to reduce energy demand as well as selling of energy, see for example, http://www.ofgem.gov.uk/docs2001/energyservicecompanies.pdf
- *Integration of heat supply into the regulatory framework:* Large scale district heating systems require large investment and a long term perspective. Liberalisation will pose difficulties to this type of systems. Many regulators' remits finish at the delivery of primary fuels (such as gas), and do not include the regulation of heat supply.

The UK has begun to take some of these issues on board, and recently the Department of Trade and Industry and Ofgem published a joint report on Embedded Generation (http://www.dti.gov.uk/energy/egwg/e_gen_report.pdf).

Parallel government support

As already mentioned, the economic viability of cogeneration is very sensitive to a number of factors and some changes occurring because of liberalisation may endanger the prospects for Cogeneration. However more and more, due to the environmental advantages of the technology, a number of governments are introducing measures to ensure that this does not happen. Such measures tend to internalise environmental costs and they are very much country specific. Some of them are fiscal measures, tariff support, quotas or targets. Some of them include the imposition of social and environmental objectives on the regulator.

Conclusions

Traditionally, energy markets have been characterised by their monopolistic structure. However in the last few years there has been a world wide trend to liberalisation, sometimes with regulation, sometimes hand-in-hand with deregulation. Indeed often, liberalisation and deregulation are mistakenly seen as the same thing. Within Europe, this liberalisation is happening in different forms and to varying degrees. The process has been consolidated by the Electricity and Gas Directives.

The extent of liberalisation and regulation is currently the most important event shaping the future energy market in Europe and it will have crucial impact in the development of cogeneration. In principal liberalisation offers new opportunities. However, new barriers may arise if liberalisation is not properly regulated. The economic viability of the technology is very sensitive to a range of factors, especially electricity and gas prices. With liberalisation new opportunities will arise, but also new barriers. The final result will be determined by the actions that the governments take to address market failures.

- Governments should ensure that the markets are properly unbundled. Unbundling of distribution and supply activities is particularly important for cogeneration;
- Governments needs to integrate environmental costs into the energy prices, and to recognise benefits of cogeneration and embedded generation;
- An arm's length, independent regulatory body is also important.
- For example, the UK has created an independent regulator (Ofgem) and has imposed social and environmental obligations on Ofgem;

The fact that the electricity market is more liberalised that the gas market (or other fuel markets) has had very detrimental effects in the development of cogeneration. In this sense the European Union started liberalisation in the wrong order.

2.1.2 High Penetration: The Dutch Experience

In a centralised electricity system, the installation of large levels of decentralised capacity can lead to problems for the utilities and grid network. This section outlines the main concerns of following a move towards decentralisation and then describes the experience of the Netherlands, which has a significant level of cogeneration capacity.

Technical concerns

Most of them fall into three major technical areas: faults, islanding and power quality.

Faults or short circuit

When a fault occurs, there is an automatic system that detects the fault and de-energises the incumbent part of the grid in order to repair the fault. The concern of the utility is that the decentralised generator may be feeding power into the grid without the utility knowing it, and therefore posing a safety threat. The decentralised generator must be able to stop feeding current when this happens. The other possibility is that the fault come from the decentralised generator, without the utility knowing. The decentralised generator must then be able to recognise the fault and separate itself from the system.

Islanding

If a portion of the system containing decentralised generation becomes isolated from its connection point, it may continue operated in an islanded fashion, and again, the utility may think that this portion of the grid is de-energised and send personnel to repair the fault. From the point of view of the utility, it is better to de-energised the island than to re-connect to a synchronised connection, but this hinders one of the main advantages of decentralised production: security of supply.

Power quality

Done improperly, connection can lead to quality problems. This is solved by developing appropriate standards.

Issues where there is no common agreement

Point of common coupling versus point of connection

This relates to at which physical point should the interconnection standards apply.

Emergency generation
Sometimes they are not connected to the grid via switchgear, so it is not possible to parallel them with the grid. The concern is that the generator provides back-feeding into the grid during an outage.

Utility interface disconnect switch
Some utilities require that a disconnect switch be associated with each potential source of electric power for safety or contractual reasons. The disconnection has to be accessible, lockable, load-break switch with a clear view of the switch opening.

Size
The utilities need to know the size of the generator in order to know how much power can be injected into the system. Decentralised generators argue that they should only be concerned with the power injected into the system.

Stiffness
The ratio of the fault contribution from the system to the fault contribution of the decentralised generator influences the power system under short-circuit conditions. If the power system's contribution dominates, then no problem. If the decentralised generator's contribution dominates, it may interfere with the existing protection and require modifications to prevent damage to personnel and equipment.

Voltage

The capability of the decentralised generator to influence local voltages on the power system is determined by the stiffness ratio. If the decentralised generator is large or the utility feeder is weak the decentralised generator must be controlled to support the utility voltage and avoid damaging the other customers' and utility's equipment. Usually however, the decentralised generator is smaller than the utility feeder, so this issue is not a problem.

Harmonics

Excessive high-frequency voltages and currents on the power system can disrupt other customers' or the utility's sensitive equipment and can cause excessive heating in transformers.

Direct current off-set

Injecting direct current into the power system damages transformers. This however only happens with micro-cogeneration schemes and photovoltaics, but can be tackled using transformers.

Flicker

Rapid fluctuations in real or reactive power cause annoying voltage fluctuations for other customers. Generally the grid is worse for this than decentralised generators.

The Dutch experience

In the Netherlands 40% of the current installed capacity is decentralised and this has pose no problems to the system. In fact, most of the Dutch utilities interviewed on this subject by COGEN Europe agreed that a system 100% decentralised is feasible. Technical connection requirements almost never constitute a reason for failure of a project in the Netherlands, while they are a frequent reason in a number of countries. The difference is that in the Netherlands distribution utilities entered into the cogeneration business after 1989, making sure that the technical connection issues were resolved in a satisfactory manner.

Key to the success of the process has been the respect both by utilities and decentralised generators of the "Technical Terms for Connection" published by EnergieNed in 1994. New terms are applicable since January 2001, but these were not examined for this briefing, as the purpose was to look into what has been done to solve the issues.

Important issues relating to connection

Safety and Availability
To prevent any kind of undesirable effect the "Technical Terms for Connection" recommend that the local production unit is disconnected by an over-voltage relay. When the unit is re-synchronised, it will automatically be coupled to the network again. The Technical Terms for Connection prescribe a regulated time to couple the unit again.

Voltage Variations
All the utilities interviewed agreed that voltage control is not a problem with increasing the CHP share. With CHP controlling arrangements such as power control and cos φ adjustments (between 0.8-1) no significant problems should arise. The same principle applies the reactive power. It is however important than CHP units are connected in close consultation with the utility or the grid administrator. Further, in the Netherlands, the capacity of the local networks is still sufficient in relation to the expected CHP growth.

Harmonic Currents
In the Netherlands, some guidelines are prepared for generating units with a capacity exceeding 11kVA. These guidelines are followed by all energy utilities. Utilities also perform measurements to see if the anticipated harmonic levels are acceptable. The damage that can be caused by harmonic currents can be prevented by using a Z-transformer.

Reactive Power Management
As long as the cos φ stated in the conditions for connection are met, the increase of CHP capacity posses no problems in terms of reactive power. This factor alone singles the Netherlands out. Most countries do not recognise the benefits of CHP to reactive power.

Short-Circuit Power
There is a general rule of thumb that says that the short-circuit capacity of the network should be 50 times the nominal capacity of the local unit (EnergieNed). The short-circuit power of a network can be increased by means of network reinforcement (e.g. a new cable, or transformer substation). Its however to the energy distribution company to decide what to do. In any case, it is also possible to connect the CHP unit at a higher voltage level. Some utilities in the Netherlands have at their location different voltage connection levels at their disposal. (10 kV, 20 kV, 25 kV or higher).

Fault currents in a network will be limited by using choke coils and by an automatic current control unit. Choke coils increase the interconnection costs, but they are only necessary in case of a weak network with a relatively low short circuit power.

Costs of connection
The costs of connection depend very much on the situation. The costs normally include a possible step-up transformer, cables, additional voltage fields in the transformer station, grounding, etc. Choke coils, if they are necessary, increase the costs. Also important are the costs for a synchronisation installation necessary to create the right conditions to connect the generator to the network, such as frequency, phase and voltage.

The connection costs for different types of clients can vary considerably. This is for example the situation for a grower far from the grid, where the existing infrastructure is often incomplete if a cogeneration should be connected. Or for industrial clients that can be located in areas where the electrical infrastructure is still not well developed. Additional costs for grid reinforcement are then necessary. The location is also an important item in another respect: if cables should cross rives or railroad lines, the costs increase considerably.

Until now, the connection costs were charged by the local energy distribution company. An approach is that the costs are billed by a onetime investment and monthly payments. As each energy distribution company has a different economical approach, the connection costs could differ for each company, but in general they were between 5 and 15% of the total investment costs of a CHP projects.

In general, connection costs of smaller units are lower than of bigger units. The smaller engines based CHP units with a capacity up to 2 MW_e are often placed at locations where the electricity infrastructure is well developed. This is not the case with large gas turbine based units, which are often located in industrial areas. Longer electricity cables as well as transformers are then necessary.

Conclusions

- Decentralised generation will become a major contributor for tomorrow's power needs, in particular cogeneration has experienced an important development in the last twenty years;

- This form of generation changes old way of operation of the electricity system, in which power flows in only one direction: from the generation plant to the end user through the transmission and distribution network. With decentralised generation, the power may flow in two directions, from the decentralised generator into the network and vice-versa. Decentralised generators are independent from the grid, and so the utility does not have control over them;
- This new way of operating posses several challenges: some are technical, but most are due to the fact that the distribution utility does not have a commercial interest in allowing the development of decentralised generators;

The experience of the Netherlands shows that the challenges do exist, but they can be dealt with satisfactorily with appropriate technical guidelines.

2.1.3 Cogeneration & EU Policy

This section is designed to give a brief snapshot of the Policy Agenda of the European Institutions and provide a commentary on the implications for cogeneration. It is necessarily brief and thus is limited to the big themes. The Policy Agenda can be divided into four broad headings:

- Liberalisation
- Security of Supply
- Climate Change and Pollution Control
- Promotion of Clean Energy

Each of these is dealt with in turn.

Liberalisation

Commission to speed up the process of the internal electricity market

The European Commission adopted three documents on 13 March on the liberalisation of the EU gas and electricity markets. One of the three documents is currently in internal consultation within the EU executive: a Communication entitled 'Completing the internal energy market'. It assesses the progress to date with implementing both the Gas and Electricity Directives, and paving the way for further improvements in a series of domains: cross-border trade, infrastructure development, public services, security of supply, environmental issues, employment and trade with non-EU countries. The other two documents are draft pieces of legislation addressing the specific issues of cross-border power trade (a proposal for a Regulation) and the review of the 1998 Gas and 1996 Electricity Directives (a draft Directive).

An overwhelming majority of Member States support the Commission's timetable for liberalisation, with only France against this issue. Germany is meanwhile continuing to oppose the Commission proposal which will oblige it to appoint a regulator who will be responsible for approving electricity and gas transport tariffs. Since the two Member States combined do not represent sufficient votes to block Commission proposals, the dossier is still on track.

This is a welcome initiative, since speeding up the liberalisation process will reduce the time for market uncertainty and bring a more open market sooner, both of which should improve the prospects for cogeneration. The proposal does not specifically deal with fair access for cogeneration to the electricity networks. However, in the introductory section it states that "it [the Commission] intends to prepare, in 2002, proposals with respect to combined heat and power (CHP)".

State Aid

These are in principle forbidden in order to ensure the correct functioning of the internal market. However exceptions may be made in virtue of other objectives of the Treaty, environmental protection being one of them. The state aid guidelines have been recently revised for environmental protection. They give extensive powers to Member States to provide support to cogeneration and renewable energy projects. These powers include investment aid, operating aid and tax exemptions. As they are very new, published in early February 2001, there is no experience yet on how they will be applied. A number of schemes to support cogeneration and renewable energy systems are currently being evaluated by the Commission for compliance with the guidelines.

This is a good step in the right direction. The important thing now is to ensure that Member States do make use of this possibility.

Security of supply

In November 2000 the European Commission launched a yearlong debate on the Security of Energy Supply, by publishing a Green Paper on the topic. The Green Paper was a thorough analysis of the subject and raised a number of questions that needed to be answered during the consultation period. As a starting point the Green Paper considered that the most important issue was energy efficiency, in that by reducing energy consumption the requirements to increase Europe's supply of energy from external sources will be controlled. For cogeneration, there is little mention in the Green Paper, which is disappointing. However, as cogeneration is an important efficiency measure the overall push for increased efficiency should assist the development of cogeneration in Europe.

Climate change and pollution control

Action Programme to combat Climate Change

This programme brought together all interested parties (technical experts, non-governmental organisations, industry and other relevant actors) to work together toward a consensus on the practical steps to be taken within the European Climate Change Programme (ECCP) to identify and develop a strategy. A final report was presented in June 2001 after 12 months making policy recommendations.

Within the proposals made is the launch of an EU cogeneration initiative, followed by the adoption of a cogeneration directive. It suggests a timetable for adoption of 2002.

Sixth Environmental Action Programme

It is shorter and more focused on strategy than the Fifth. It covers areas such as Climate Change chemicals, health protection, and managing natural resources. The European Parliament is likely to propose amendments strengthening the position of cogeneration in the Programme and asking for support measures for the technology.

Emissions of certain pollutants from Large Combustion Plants

When finally approved, it will require that all new plant over 50 MW_{th} be developed as cogeneration unless this is not technically and economically feasible. This could provide an important boost for cogeneration.

Integrated Pollution Prevention Control

The EU has a set of common rules on permitting industrial installations. These are laid down in the IPPC Directive. Unless new installations have a permit, they can't operate. The permits are based on the concept of Best Available Technologies. Existing installations have an 11-year transition period to comply with the rules.

National Ceilings for acidifiers and ozone precursors (proposal for a Directive)

Proposes national ceilings for each member state, to be achieved by 2010. The EU will have to modify approaches to energy conversion, thereby facilitating the move towards cogeneration.

Emissions Trading

This Green Paper will help to prepare for an EU greenhouse gas emission trading system to be launched by a target date of 2005, 3 years before entry into force of an international regime. It defines emissions trading as a scheme whereby companies are allocated "quotas" for their emissions, according to national reduction plans. Those reducing more than their quotas can sell their surplus that should lead to one price for quotas traded by companies within the scheme. CEC suggest that the scheme should confine itself to large fixed point sources of CO2 in the following sectors: electricity and heat production, iron and steel, refining, chemicals, glass, pottery and building materials, cement, paper and printing.

DG Environment has drafted a proposal for a Directive on Emissions Trading. This draft is currently in inter-service consultation and is expected to be published in the next few months.

The correct design such a system should benefit the cleanest and most efficient systems, which will include cogeneration. However, there are worries that with a system that initially rewards poor performance – grandfathering – there will be disincentives for cogeneration. Some commentators have expressed concern that it could have a negative impact on cogeneration, especially if both heat and power production is subject to CO2 quotas.

Promotion of clean energy

Taxation of Energy Products

This proposal for a Directive has been in the pipeline for a long time. Taxation requires unanimity and this is very difficult to achieve. There are signs that Spain, the country that was most reticent to accept this proposal, may soften its position.

Action Plan on Energy Efficiency

The Action Plan points out ways to co-ordinate activities within member states and reinforces and refocuses ongoing activities. It also discusses options to promote cogeneration.

EU Renewable Energy Directive

The Directive proposes several ways to promote these technologies, including biomass cogeneration, as well as non-legally binding targets.

Enlargement

There are 13 Candidate Countries in list of countries to join the EU. Acceptance of the acquis communautaire is one of the conditions to join the EU. Air pollution has been identified as one of the key environmental problems in the area, and the EU has put forward several financial instruments to help solving this problem. Examples are the PHARE and the ISPA Programmes.

First outcome of liberalisation

Although in principle liberalisation should be beneficial for the development of cogeneration; the first outcome has been disastrous. This is mainly due to the fact that externalities (such as environmental costs) are not included in the energy prices, as well as to other market failures. Several member states have recognised the existence of these market failures and began addressing the necessary measures to ensure that liberalisation does not result in the death of clean technologies such as cogeneration and renewables.

Conclusions

- The EU does not have far-reaching competence in Energy matters and in many areas of energy policy various articles in the Treaty establishing the European Community cover these. As there is no energy chapter in the treaties and, therefore, no firm legal basis, energy legislation has to be based on other legal bases, such as the liberalisation processes are undertaken under internal market articles and the directive on energy performance of buildings was based on environmental protection. However, there are currently a number of policy initiatives at EU level affecting cogeneration
- Most of these initiatives are moving in the right direction for the cogeneration industry.

2.1.4 District Heating: Central and Eastern Europe

Background

Domination of District Heating

District heating is a dominant energy supply source in the Central and Eastern European (CEE) countries, as about 40% of the population are customers of district heating networks. Additionally, the general condition of the district heating networks is not good. Many district heating systems seem to be oversized in terms of installed capacities compared with the actual heat demand. In some countries, the installed heat generation capacities exceed actual heat load requirements by some 50%. At the same time, large sections of district heating systems are achieving or exceeding the limits of their technical lives and are overdue modernisation. This is leading to low system efficiencies. There are also problems associated with the poor condition of the heating networks which suffer from oversized diameters, corrosion, leakage and inadequate pumps. Improvements are also required in metering the heat outputs.

The energy markets in most of the CEE are currently being liberalised. Consequently, there is an enormous public and political focus on issues such an environmental protection, savings of scarce resources, and indeed on the local economy. All of the countries state that district heating has an important input to offer in these issues, especially from cogeneration, which has proven to be a central technology in the attempt to balance the objectives of a free market and environment pressures. District heating therefore provides an important basis for further cogeneration expansion.

A common interest of all of the countries is the security of energy supply at affordable prices, the creation/extension of energy networks and a reasonable price policy, especially where all subsidies have been withdrawn. To be more competitive, the district heating utilities and companies have extended their business by introducing new products and services mainly relating to district heating. Aggressive marketing is needed to launch these new products to customers.

Advantages of district heating

The main advantage of district heating is the reduction of environment pollution in comparison with operation of local heat sources. The other common advantages of district heating and cogeneration implementation in the CEE are:

- increasing of efficiency (average from 37% in condensing plants to 70% in cogeneration)
- security of heat supply in towns and cities
- limitation of long-distance energy transmission
- reduction of fuel consumption

The CEE countries are significant users of coal and gas for district heating, as well as for the thermal and electricity sectors. This creates a large potential for the use of more diversified energy sources, such as renewables and wastes (biogas, solid wastes). Another potential future market is for district cooling applications. Absorption chillers connected to district heating systems can, in the summer time, convert heat to cold to the benefit of the consumer. Such systems are already operating in EU (for example in the United Kingdom, Germany and the Netherlands), and will be implemented in the future in the CEE, as consumers become aware of its advantages relative to electricity driven devices.

Potential for district heating

Since the share of district heating in heat supply systems in most of the CEE is high, there is little potential for further growth. However, by introducing regulations and legislation promoting connection to district heating, there still is some potential. The small growth potential is further reduced by the transformation period in all of the post-communism countries. Total energy demand has fallen in tandem with economic recession, primarily in the industrial sectors of economy. Therefore, current efforts are focusing on improving the efficiency of existing district heating systems and the maximum use of their capacity, with new consumers being connected to existing district heating systems.

As district heating systems are struggling to be economically competitive under current market conditions, a change in approach towards hat production is required. The heat produced needs to become a "good", which must be sold through market driven processes, in which all cost elements must be incorporated. An essential element of this change is the drive towards environmental protection.

Markets

Market for new district heating development

The benefits of cogeneration expansion is clearly recognised in the CEE. Only cogeneration will allow a reduction of heat prices. Gas will become more important as a fuel, especially in countries like Poland and the Czech Republic, where coal-fired boilers are already being replaced by gas turbines. There is also a growing recognition that the fuel mix must change in order to promote environmental requirements, which will help, in the future, to put an emphasis on natural gas and renewables.

Apart from the very high dependence on domestic coal, it is remarkable that the use of renewable an waste sources is practically zero in the region. Small contributions can be found, but this potential is largely unexploited. Therefore, the process of technological modernisation is also aiming to create new district heating sectors, based on non-conventional energy sources.

The promotion of cogeneration is becoming a priority objective of the strategy for development of the district heating sector. Consequently, in most of the CEE countries, a market-oriented Energy Law has been already adopted, or is being implemented.

District heating cogeneration economics

Cogeneration provides the most cost-effective option for power generation when the savings from heat consumption are taken into account. In countries with a more liberalised electricity market, cogeneration can usually be developed more freely than in markets where regulated tariffs are set.

The are two major factors that affect the economics of cogeneration in the CEE. These are related to the type of installation and to the regulations and legislation applying to cogeneration. In many cases, return on investment will be achieved within three to five years. However, cogeneration is a major investment and the option needs to be carefully examined before a decision about construction is made. As a cogeneration plant normally runs for at least ten years, a full life cycle cost analysis must be undertaken. This analysis should take into account variations in fuel, electricity prices, and energy demand over the lifetime of the plant. The pricing of district heating is very important if it is to achieve increased penetration in the CEE.

Heat prices in the CEE vary form 16.5 Euro/MWh in Bulgaria to 35 Euro/MWh in Estonia, with VAT from 0% (Estonia) to 22% (Poland, Romania). The cost of heat to households in the region is, on average, 25-50% greater than in the EU. There are several reasons for this. Firstly, the economic restructuring in CEE region was difficult for the district heating sector and many industrial clients have disappeared. This leaves the utilities with over capacity and limited opportunity to recover costs. Secondly, in some countries in the region, a political preference towards other sources of heating has created cross-subsidy schemes to the detriment of district heating and cogeneration.

Cogeneration and district heating

Cogeneration has been a feature of energy supply in the region for over 60 years. The majority of the capacity is located in the district heating and industrial sectors. Owing to this age, the sector is inefficient, but there are two straightforward ways in which improvements are being made. Firstly, there is a big potential for reduction in losses, be they demand side management measures that will decrease wastage at the consumer, or the reduction of system transport losses. Secondly, there is the potential to invest in new efficient cogeneration plant. This need to modernise plant has been recognised in the majority of the CEE countries, which have included cogeneration in their energy strategies. Legislation, tax and pricing instruments will be used to develop an economic environment supporting the effective development of cogeneration.

Advantages of cogeneration for district heating

Cogeneration versus conventional power generation.

Cogeneration is one of the only energy generation processes which can help to reduce CO_2 emissions. It also has a high efficiency, converting 85-90% of the energy content of the fuel, compared with 30-40% for a conventional condensing power plant.

Cogeneration plants generally have a high level of availability, enabling uninterrupted energy production. Cogeneration plants also can be highly automated, reducing staffing levels and keeping operation and maintenance costs low.

In contrast to conventional power stations, solid fuel-fired cogeneration plants using fluidised bed technology do not require separate desulphurisation plants to reduce emissions to meet regulatory requirements. In the cogeneration process, emissions such as sulphur are controlled by the injection of limestone into the combustion chamber and nitrogen oxide emissions are restricted by optimising the combustion temperature.

Industrial wastes, with a low calorific value and high moisture content, can also be burned in a cogeneration plant, again using fluidised bed burners. This helps companies simplify their waste disposal management, and eliminate most alternate waste disposal needs.

Advances in the technology are making it possible to use cogeneration for smaller-scale local energy production units across the commercial, industrial and public sectors. In the past, small scale cogeneration was less attractive, as energy savings obtained from these plants were less significant owing to the lower relative electricity output from these plants.

Recent technological innovations have also made efficient cogeneration possible at the micro level. This has opened a world of opportunities for using cogeneration plants in small commercial and even single-home installations.

Policies

Policy rules affecting district heating & cogeneration

Some of the CEE countries have a special regulations concerning cogeneration (Bulgaria, Latvia, Lithuania, Poland, Slovenia). In others (Czech Republic, Estonia, Romania), there is no legal framework dealing specifically with cogeneration. Energy legislation In the first group of countries has established an obligation to buy the electricity produced from cogeneration. They also oblige the district heating companies and power utilities to open excess power and heat to the network through third party access arrangements. In Poland, the power supply companies are additionally obliged to purchase electricity produced from non-conventional energy sources.

In most countries the production, processing, storage (gas), transmission, dispatching and distribution of energy and fuels may only be carried out upon the grant of the licence.

Cogeneration implementation is strictly connected with state environmental policy. Air pollution is considered as one of the main environmental problems in the region, especially in countries with domestic coal resources. The last version of Polish energy Policy 2020 assumed that the share of renewable resources will increase to 15% in 2020 (from 4% in 1999). Therefore, the improvement of energy efficiency and environmental pollution reduction can be achieved by wider use of cogeneration in district heating and industrial plants, as well as in smaller systems.

Most of national Energy Strategies state that liberalisation, restructuring and commercialisation of the energy sector are a key national consideration. The second level issues are the opening of competition, reliability of the energy supply and, state energy security (fuel diversification), and clear tariffs and price policies.

Accession to the EU is another factor driving cogeneration developments in the CEE. Poland, Estonia and Latvia have set up a legal and regulatory framework for the energy industry in accordance with EU regulation. They declared a favourable environment for private investment in cogeneration, the utilisation of renewable resources, as well as for energy efficiency measures.

Conclusions

Cogeneration that is designed to meet the heat load of the facility brings many benefits:

- More efficient energy conversion
- Lower emissions of greenhouse gasses, particularly CO_2
- Significant cost savings, making industrial and commercial users more competitive, and bringing domestic users affordable heat
- Local power distribution. Greater decentralisation of electricity generation avoids long distance transmission losses
- Improved security of supply - local cogeneration can reduce the risk that consumers are left without energy supply. This reduced fuel need also reduces fuel import dependency
- An opportunity to increase the diversity of generation plant, and provide competition in generation. Cogeneration provides one of the most important vehicles for promoting liberalisation in energy markets.
- Increased employment - a number of studies show that cogeneration development creates jobs

Today the most frequent barriers to the wider use of cogeneration are:

- High tariffs for stand-by and top-up supplies from outside energy sources
- Inadequate payments for grid sales of surplus power
- Long payback, arising from unfavourable economic and regulatory circumstances, continues to be an important barrier in most countries
- Few countries have free access to the electricity network. In some, while allowed, it is restricted and costly
- Bureaucratic procedures for obtaining all required authorisations
- Lack of awareness of the technology and lack of government awareness of the economic and environmental benefits of cogeneration
- Fuel taxes are often unfavourable to cogeneration. The environmental costs of energy production are not properly integrated in the price of fuel, and as a consequence, natural gas and other fuels becomes relatively more expensive
- Emissions regulations do not take the higher efficiency of cogeneration systems into account
- A new barrier in some countries relates to uncertainty arising from changes in the electricity market
- In countries which have high nuclear capacity, there is little potential for cogeneration development
- Limited availability of natural gas, presently the favoured fuel for cogeneration, is a problem in some countries

2.2 TECHNOLOGIES AND APPLICATIONS

This section presents the technologies and applications that will be the long-term future of cogeneration in Europe. Gas fired cogeneration is already the fuelling option of choice, but the potential for applications is huge.

2.2.1 Micro Cogeneration & Economic Review

Micro cogeneration is a “disruptive technology”. It has the potential to substantially disrupt the established electricity supply industry both economically and technologically. It has a predicted capacity of similar order of magnitude to the existing nuclear generating capacity in the key emerging liberalised energy markets in Europe.

Micro cogeneration, installed in individual homes, will in time remove a substantial electricity demand on a dynamic basis at the low voltage level, and may, in some instances, neutralise or even reverse the power flows in distribution transformers. This will clearly have economic consequences for the Distribution Network Operator (DNO) in terms of lost revenue, but will also have profound consequences for LV network design.

The economic opportunities, and to a lesser extent environmental drivers, which are leading to the imminent advent of micro cogeneration, will disrupt and will require a response from electricity companies. There are those who will no doubt seek to obstruct the new technology and maintain the status quo of their business. However, in the long term, the considerable economic benefits to the operators of micro cogeneration should prove irresistible. At the other extreme are those companies who will enthusiastically embrace the new technology and significantly improve their competitive position. These latter companies are already in the process of establishing strategic alliances with technology providers, manufacturers, service, installation and energy service companies and are acquiring technical and commercial experience by undertaking laboratory and field trials.

A range of micro cogeneration technologies are approaching commercial launch and the remaining challenges relate less to core technology and more to peripheral and interface components and commercial packaging.

It is at this stage that the implications for energy companies, suppliers and network operators, are becoming clearer. In general these challenges fall into two main areas, commercial and technical. Within the commercial area, the complexity of metering and settlement of domestic import/export represents a formidable challenge, whilst the technical standards appropriate to integrating numerous very small generators raises entirely new issues both at the customer interface and throughout the LV network.

This report aims to summarise the status of micro cogeneration technologies, potential applications and scope of markets. It describes the potential commercial and technical impact on existing electricity companies, their networks and customer base as well as identifying likely new market entrants.

Background

The UK government has identified cogeneration as a key component of its CO_2 abatement programme and it also represents a significant individual measure in achieving the European Union’s CO_2 reduction targets. In order to meet the CO_2 emission reduction targets agreed at Kyoto, the EU has set a target of doubling the share of cogeneration in total electricity generation from 9% in 1994 to 18% by 2010. Meeting this target is expected to lead to CO_2 savings of around 65 Mt.

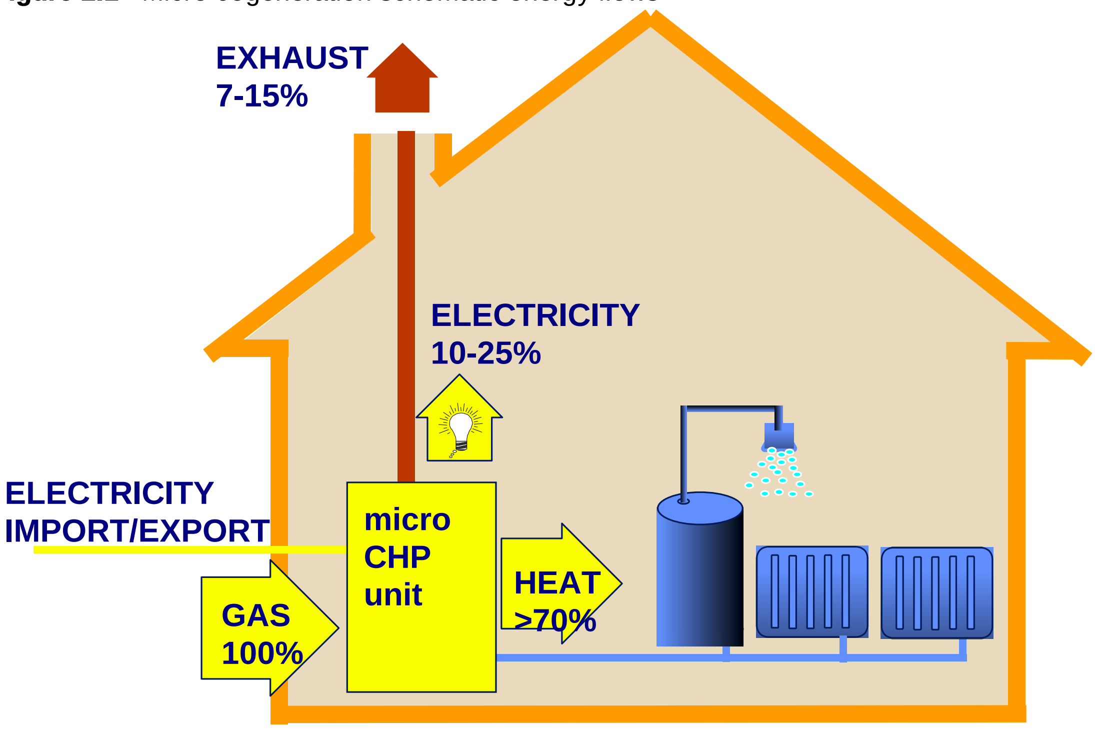
However, it is now clear that the emerging micro cogeneration technologies which were not included in this original target may help to make up for the disappointing growth currently being experienced in conventional cogeneration markets. Cogeneration generally represents a cost effective CO_2 abatement measure and micro cogeneration is potentially an even more cost effective measure. Perhaps more importantly, it can be readily implemented in the vast majority of existing homes for which relatively few substantial energy efficiency measures can be implemented in a realistic commercial manner.

Sceptics might question the potential for micro cogeneration on a significant scale in a market which has been so hostile to conventional cogeneration and where market development has stagnated and even in some countries, where existing cogeneration plant is no longer being operated. However, the causes of this severe economic environment are less applicable to domestic cogeneration. In markets that have opened to competition, prices of electricity have fallen due to the incumbent generators' use of amortised plant to undercut new market entrants who have to finance their investment from improved overall efficiency. It is not surprising that the use of anti-competitive, predatory and unsustainable pricing has had an adverse effect on cogeneration developers, particularly those intending to supply large industrial customers. Recent developments in gas prices have further undermined the economic case for larger scale cogeneration, as the gas/electricity price ratio has become unattractive to those who do not have long term gas purchase contracts. Although domestic customers have seen significant real electricity price reductions since privatisation in the UK, domestic prices are still considerably higher than industrial prices. More significant though is that the element of these prices represented by the energy component is relatively small, at least 50% comprising transport charges and other overheads. The avoided cost of supply of power can be generated at a domestic customer's point of use, which therefore has substantial economic benefits which are less susceptible to predatory energy pricing. At the same time, the gas prices which are causing such anguish to industrial cogeneration operators have virtually no impact on micro cogeneration. As will be explained later, the implementation of micro cogeneration has a negligible effect on gas consumption, and an increase in the price of gas has an almost identical effect with or without micro cogeneration.

Micro cogeneration concept

For those unfamiliar with the concept of micro cogeneration it may be helpful at this stage to consider the basic principles of operation. Although the energy flows indicated in figure 2.1 apply to Stirling engine based units, the illustration can be applied conceptually to other technologies including fuel cells.

Figure 2.1 - Micro cogeneration schematic energy flows



Natural gas is consumed in a Stirling engine (or other prime mover) to provide heat and electricity for use within the home. (Note that the figures in the diagram above are for illustrative purposes and depend on the specific technology as well as the actual product under consideration.) A total of 70% (GCV) of the energy value of the gas is converted into heat, principally in the form of hot water which is used for space heating and domestic hot water as in a normal central heating system. Between 15-25% is converted into electricity, and the remainder (5-15%) is lost in the flue gases. This compares with a conventional gas central heating boiler (representing around 95% of boilers in the UK), where 70% of the energy in the gas is converted into heat and the remaining 30% is lost in the flue gases. The electricity generated in the home has a value, which covers the investment cost of the micro cogeneration unit and provides a net saving.

Although there are those who consider generators of 3 kW_e and below to be somewhat trivial, the key to micro cogeneration is the very large numbers of units which may be installed and their significant cumulative impact. Based on a simplistic model considering end-user economics as the basis for implementation, micro cogeneration has a potential installed capacity of 15 GW in the UK alone of a similar scale to the nuclear industry. A more recent study considering the more complex, but more profitable economics from an ESCo perspective indicates a potential market for micro cogeneration product sales alone in excess of 1,000,000 units or Euro 3 billion annually throughout Europe.

Impact on energy supply companies

The economic impact of micro cogeneration should be a major cause of concern to energy companies. In a competitive market where wholesale power is available to all at the same price and DUoS (distribution) and TUoS (transmission) charges are equitable and transparent, there is very little margin and little scope for competitive advantage unless a company has some technological or commercial edge over competitors.

Micro cogeneration provides just such an edge, by delivering electricity at a lower cost than is possible through the conventional distribution chain. Let us consider first the end-user economic case. Although it is unlikely that end-users will install and own micro cogeneration units, this simplistic approach at least identifies and quantifies the economic issues. It is assumed that micro cogeneration units will be installed in homes to replace existing gas boilers which have reached the end of their useful life. The householder is then faced with the choice of installing a new gas boiler (of which 95% in the UK are conventional boilers with a seasonal efficiency around 70%), or a micro cogeneration unit. Naturally the micro cogeneration unit is more expensive than the boiler, but the additional investment cost is repaid from the savings in electricity bills as well as the value of electricity sold back to the electricity supply company. The marginal cost varies depending on the micro cogeneration unit selected, a factor which determines the appropriate market for each product. The two examples below consider the 3kW_e Sigma unit and the 1 kW_e WhisperTech unit with marginal costs of Euro 2400 and Euro 960 as representative products for larger and smaller homes respectively.

On the basis of this simplistic model, it can be seen that both products have a payback of around 4 years. However, no account is taken of the benefits to the electricity supplier of the reduced cost of supplying such customers and, seen from the electricity supply company's perspective, the economics of micro cogeneration are even more attractive. The reduced demand will, however, result in loss of revenue for the DNO (Distribution Network Operator).

Table 2.1 - Calculation of economic viability

Example 1) Sigma (3kWe/9kWt) unit installed in a large UK family home with an annual heat demand of 27000kWh.

		kWh	*Euro*
Annual heat demand		*27000*	
Running hours	*3000*		
Electricity generated		*9000*	
Own use of generation	*45%*	*4050*	
Unit cost of avoided import			*0.11*
Value of avoided import			*454*
Generation exported		*4950*	
Unit cost of export			*0.05*
Value of export			*238*
Total value of generation			*693*
Marginal cost			*2400*
Simple payback (years)	*3-4*		

Example 2) WhisperTech (1kWe/6kWt) unit installed in small UK family home with an annual heat demand of 15000kWh.

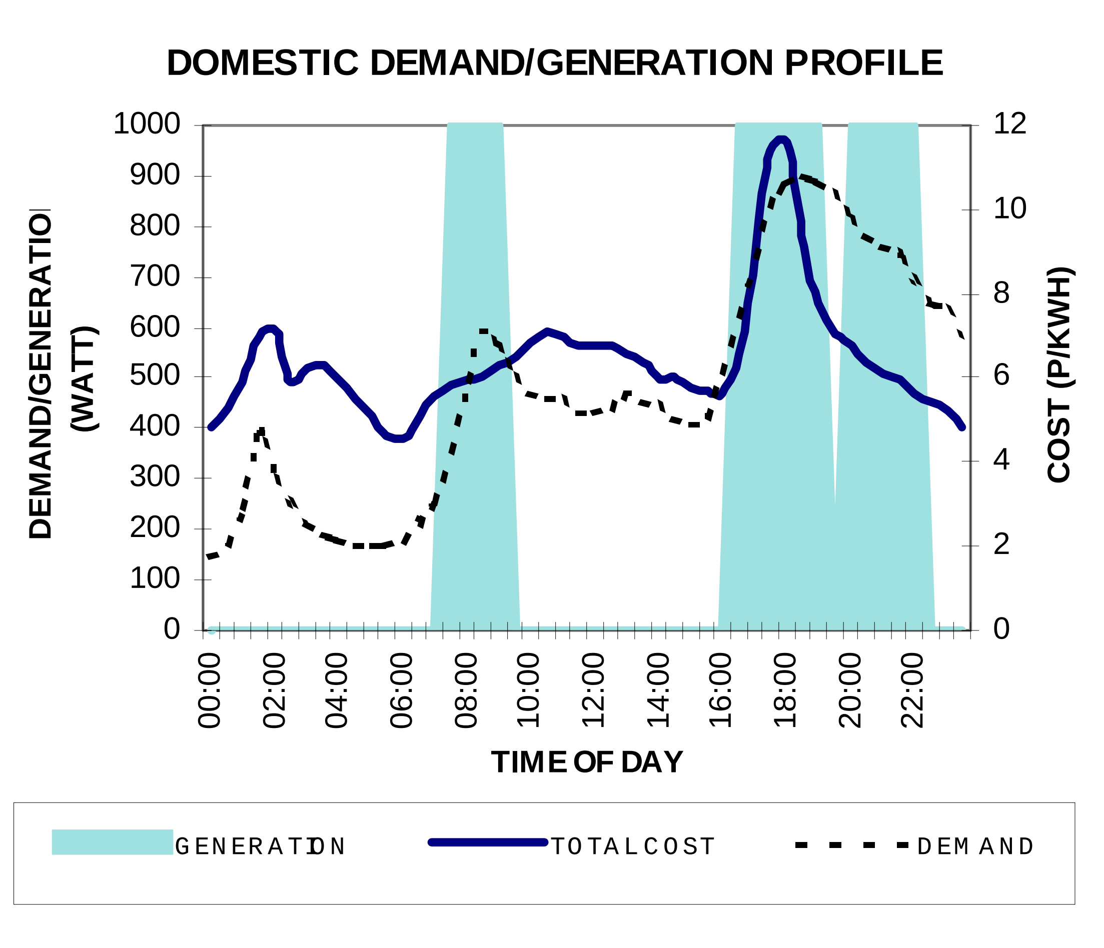
		kWh	*Euro*
Annual heat demand		*15000*	
Running hours	*2500*		
Electricity generated		*2500*	
Own use of generation	*70%*	*1750*	
Unit cost of avoided import			*0.11*
Value of avoided import			*197*
Generation exported		*750*	
Unit cost of export			*0.024*
Value of export			*18*
Total value of generation			*214*
Marginal cost			*960*
Simple payback (years)	*4-5*		

The electricity generated in a micro cogeneration unit is available to the energy company at the point of demand. Although it has high value (based on generation profile and point of generation) it can be sold to customers at a lower price, whilst simultaneously giving a higher profit margin. In the UK, a typical equivalent profit of less than Euro 9.6 per customer can be increased to as much as Euro 590 for a large family home and around Euro 240 for a smaller home.

The reason for the high value attributable to micro cogeneration generation is that it is produced at the time of highest wholesale price and at the geographical location where it is required. This latter point simply means that the transport cost is eliminated and the cost of supply reduced by more than 50%.

Micro cogeneration operation is thermally led, that is the unit operates when there is a demand for heat, and electricity generation is a by-product. As the pool price is substantially influenced by domestic loads and these coincide with periods of peak thermal demand, micro cogeneration units tend to operate most during periods of highest pool price. Micro cogeneration generation is therefore worth considerably more than the average pool price. Even if most of this power is consumed on site by the householder so that the resulting export occurs only during less highly priced periods, (such as is the case for smaller output units such as the WhisperTech product), the cost of supplying the home is reduced. Figure 2.2 shows this variation of cost and demand during a typical winter day, illustrating the value of micro cogeneration generation.

Figure 2.2 - Variation of electricity value for typical winter day



Variation of electricity cost throughout a typical winter's day shows the value of micro cogeneration generation. Generation coincides substantially with peak supply cost, as does domestic demand. Demand weighted value of micro cogeneration is around Euro 0.054/kWh over the year compared with an average pool price less than Euro 0.045/kWh

However, even though the value of generation varies with time, the complexity of half-hourly metering and settlement would be prohibitively expensive under current conditions. Net metering has been advocated, both in order to simplify the process and to act as an incentive to encourage such an environmentally beneficial form of generation. This is likely to meet with justifiable resistance in a competitive market and is clearly unsustainable in the long term.

However, net metering against a modified unit rate provides the benefits of simplification without imposing unrealistic economic demands on the DNO. This concept is already widely used for domestic supply settlement. Domestic loads vary substantially with time, despite being charged at a fixed tariff. Settlement based on a relatively small number of representative load profiles is used to arrive at a demand-weighted cost of supply for domestic customers. There is no apparent reason why the same logic could not be applied in reverse, although it would require monitoring of a number of micro cogeneration installations to build up a database of representative profiles. It may well be that intelligent meters, capable of half hourly point of supply settlement, will become available within the next few years, providing an alternative settlement method.

Impact on generators

In terms of investment cost per kW, micro cogeneration is also set to become the cheapest form of new generating capacity, particularly if infrastructure costs are included in the calculations (assuming micro cogeneration units are installed as drop-in replacements for obsolete gas boilers). However, financial considerations are not the only motivating factor for companies aiming to acquire generating assets or to achieve customer growth. Compared with conventional central plant solutions, micro cogeneration offers a wide range of benefits including avoidance of planning, resource and pollution consent problems, low incremental risk, short lead times, flexible location, and reduction in network losses.

Micro cogeneration as an ESCo business

The direct competitive benefits arising from micro cogeneration are significant in their own right. However, having once established an energy supply business with an unassailable competitive edge, it is possible to package the offering in such a way as to exploit a range of additional commercial opportunities in the delivery chain. These may well represent a substantially greater profit stream than micro cogeneration itself. UK householders are notoriously reluctant to invest in energy efficiency devices even with significant, short paybacks. This inertia can be exploited by offering an ESCo package with a guaranteed total bill lower than previously. Within this bill would be profitable product supply and leasing, installation and service business as well as highly profitable energy supply.

Impact on distributors

We have seen that, from an investment and operational perspective, micro cogeneration offers significant competitive advantages. The competitive advantage it confers on the participants is however, seen from the outsider's perspective, a significant threat to existing and future business. It can result in loss of customers and stranded assets. At the anticipated level of market penetration, micro cogeneration generation, fed into the network at low voltage, may begin to have an impact on network stability within a decade, with implications for network design (to accommodate reverse power flow) and asset recovery.

The potential number of micro cogeneration installations will require a fundamental reassessment of network design and on technical standards for connection. The cost and manpower requirements, both to micro cogeneration operators and to DNOs of complying with current engineering standards intended for substantial project engineered generators (such as G59), are excessively onerous and inappropriate for 1 kW_e generators. An agreed EU standard is therefore required as a matter of urgency and work in this area has already commenced.

Environmental considerations

The full impact of the emissions targets agreed at Kyoto has yet to be felt, but a number of EU governments have implemented pollution taxes, or incentives such as exemptions for improved performance. Already the UK has a Climate Change Levy (CCL) and Denmark has set a price of up to $13 per tonne for CO_2 emissions. It is probable that CO_2 emission quotas will become tradable and that consequently, products such as micro cogeneration will acquire an increased value to their owners, particularly if those owners are energy companies.

The actual mitigation effect of micro cogeneration will depend on the particular technologies to be implemented and the generation mix they displace. On the assumption that it will be the most cost-effective forms of emission reduction that will be implemented, micro cogeneration generation will initially displace the most inefficient and polluting existing generating plant, which in the UK is older coal-fired plant without flue gas desulphurisation. Compared with this plant, the annual reduction in emissions achieved by each typical (3kWe) micro cogeneration unit is 8.8 tonnes CO_2, 136 kg SO_2 and 50.4 kg NO_x. Taking the eventual market for the units at an estimated 15 GW in the UK and a similar figure for Germany within 15 years, the potential for reduction in CO_2 emissions alone is 45 million tonnes. On an individual basis the CO_2 quota would add about one third to the economic value of the micro cogeneration unit.

However, as the market develops it cannot be assumed that all displaced generation is coal and a more realistic figure would be 6 tonnes annually for this unit, based on a projected displaced generation mix of 700g/kWh.

Fuel cells with a rather high power/heat ratio would have a larger environmental impact on an individual basis, but the level of market penetration in the EU is likely to be relatively low for the foreseeable future. However, even within the Stirling engine based products there is a fairly broad range of impacts varying from the Sigma 3kWe/9kWt unit with a relatively high electrical conversion efficiency leading to 8.8 tonnes CO_2 saving per year, to the WhisperTech unit with a lower electrical output (1kWe) and efficiency resulting in only about 1.7 tonnes CO_2 saving.

Conclusions

Micro cogeneration represents a potentially disruptive force in the evolving European power markets. It is set to have a considerable impact on the technical and commercial shape of the emerging liberalised electricity market.

The combined influence of economic and environmental drivers, coinciding with technological maturity, has established a framework in which micro cogeneration is likely to become a reality within two years. It will achieve a significant impact within five years and market saturation within a 10-20 year time scale.

Given an equitable market framework, these drivers will be sufficient to achieve the predicted market penetration rates without artificial incentives.

However, there are two key factors determining the growth of micro cogeneration, which lie within the ambit of government agencies. These are, firstly, the regulation of connection agreements (both from a technical and commercial viewpoint), and the introduction of simplified metering, settlement and trading procedures.

Without the imposition of equitable, transparent connection charges and technical standards, it will be impossible (legally) to connect micro cogeneration systems without costly and counterproductive components in the system.

Without simplified metering and settlement procedures, it will not be possible to obtain the maximum value from micro cogeneration generation and thus extend the market and economic viability of the technology.

Market potential

Within the EU15, the potential for micro cogeneration may be summarised as follows:

- Ultimately micro cogeneration will provide an installed generating capacity in excess of 60GW
- In two key markets, UK and Germany, this capacity will be roughly equivalent to the existing nuclear generating capacity
- 40 million homes are suitable for micro cogeneration
- Ultimately micro cogeneration will contribute an annual reduction of 200 million tonnes CO_2 to EU mitigation targets, somewhat greater than the currently

anticipated total for all cogeneration measures, which take no account of micro cogeneration

- Within the context of the Kyoto timeframe, it is anticipated that 1 million systems will be installed annually by 2010, representing an annual saving of 15 million tonnes of CO_2

Recommendations

Urgent government action is required if the target market launch dates and subsequent growth and CO_2 mitigation levels for micro cogeneration are to be achieved. It is anticipated that the first Stirling engine based micro cogeneration products will become available on a commercial basis during the first half of 2002. These measures therefore need to be completed prior to early 2002. Specific measures proposed are:

- Establish EU and national working groups to develop appropriate connection standards and cost methodologies for connection of micro cogeneration units within the home and to the network
- Establish an industry-wide methodology for simplified metering and settlement of micro cogeneration exports (this will also be required for other micro embedded generation technologies such as PV). This may take the form of profile settlement as currently used for domestic supply trading or net metering with an appropriate allocation of distribution network costs
- Empower national electricity industry regulators (where these exist) to implement the standards developed by these groups

In addition to these measures, the targeted implementation of carbon tax exemptions or similar reflection of external cost mitigation may directly influence the rate of growth of the micro cogeneration market and the consequent rate of carbon mitigation.

2.2.2 Biomass Cogeneration

One of the technological options for cogeneration is to use biomass as a fuel. With the exception of Finland and Denmark, biomass cogeneration capacity in Europe is small. This market is under developed owing to a number of reasons, primarily linked to plant economics, fuel supply sources and proactive policies from government. The potential for biomass cogeneration has been significantly boosted by the introduction of the draft Renewables Directive[8], where biomass electricity generation is expected to play a major part in the achievement of the 22% of gross electricity consumption target.

This section uses the experiences gained in Finland to review the experiences gained from a country with significant levels of biomass cogeneration penetration.

The Finland Experience

Finland has long traditions using biomass cogeneration technologies. The first industrial cogeneration plants in Finland were built at the turn of the 1920s and 30s, and the first district heating plants in the 1950s. The aim was to increase the economy and reliability of power supply, and local energy sources were often used as a starting point.

The Rankine cycle continues to be the prime power plant technology, when biomass power plants are built. Although new technologies are being developed, practically all industrial

[8] COM (2000) 884: Amended proposal for a Directive of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market

plants employ the Rankine cycle. A Rankine power plant has three main sections: fuel handling, boiler plant, and steam and power section.

Grate combustion systems in various forms have a long history of use solid fuels. Grates are still used in many small and medium sized boilers for hot water and steam production. They have been able to compete with more modern technologies and more convenient fuels due to continuous improvements and the use of modern control systems. However, grates are less flexible than fluidised beds with regard to fuel quality and less suited to variable fuel mixtures and variable fuel quality.

Competitive and environmentally compatible energy use of biomass requires combustion technology able to cope with the special requirements of biomass. Fluidised bed technology can be applied to a very wide range of fuels, from very moist fuels like bark and sludges up to high-grade fossil fuels. Fluidised bed boilers achieve fuel efficiency rates of over 90 per cent even with difficult, low-grade fuels.

In fluidised bed combustion (FBC) the large capacity of inert bed material helps stabilise combustion process, an important benefit when biomass with its typically large variations in fuel properties is burned. The low operating temperature of FBC boilers, coupled with stage combustion, effectively reduces formation of thermal nitrogen oxides NO_X. If lower NO_X levels are required injection of ammonia or urea can be used.

Separation of suspended solid particles from the flue gases is the costliest emission control operation required by FBC boilers. The standard solution is to fit the plant with an electrostatic precipitator (ESP).

The fluidised bed boilers can be divided into two types

- bubbling bed type (BFB)
- circulating type (CFB)

The choice between bubbling fluidised bed (BFB) and CFB technology has been largely linked to the choice of fuels. As the simpler and cheaper technology, BFB has been favoured for plants exclusively fuelled with biomass or similar low-grade fuels containing highly volatile substances. The new enhanced CFB designs can be a competitive choice even in smaller biomass-fired plants (>5 MW_e). CFB boiler has been the choice when sulphur-containing fuels are used. For reactive fuels like wood, wood wastes or peat both types are applicable.

In the size class of less than 3 MW_e, the main alternatives for electricity production are:

- Gasifier or direct combustor combined with a small steam turbine or steam engine: this alternative has a rather low power to heat ratio (due to inefficient small steam cycle) and the specific investments are high. On the other hand, this process concept is the only alternative that can be considered to be fully commercially available.
- Direct wood-fired gas turbines: these systems have been developed both in USA and in Europe, but so far none of the developments has been successful. The main reasons for this are: a) alkali metals released in combustion cause rapid corrosion in turbine blades, b) pre-treatment of wood into dry powder is expensive, and feeding of pulverised wood into pressurised combustors is also problematic.
- Stirling engines seem to approach commercialisation and their best market may be in the smallest size range (<500 kW_e). The recent development in Denmark seems to be promising, but probably a few years are still required until the technical and economic performance of Stirling engines can be reliably estimated.

Small-scale gasifiers may also have some advantages compared to direct combustion-based systems in Stirling applications (more easy to avoid erosion and corrosion and to control combustion conditions).

- Production of pyrolysis oil on a larger scale and distribution of produced oil to small-scale engine power plants: the technical feasibility of pyrolysis oil combustion in diesel engines has so far not been demonstrated, but there are several R&D projects going on and it is possible that this technology will become commercially available within a few years.
- Fixed-bed gasifiers coupled to diesel or gas engines are the focus of many R&D projects in Europe at the moment. There are several industrial development projects, e.g. in Switzerland, Germany, Denmark, UK and the Netherlands, with which the fixed-bed gasification technologies (Finnish version; Novel gasifier combined with catalytic cleaning) will compete in the future. Most of the competing technologies are based on slightly modified classical downdraft gasifiers. In Denmark and UK, there are also teams utilising updraft fixed-bed gasifiers and having tried to develop catalytic gas cleaning systems. However, so far these developments have not led to commercial breakthrough.

Many different types of gas generators have been developed over the 100 years the technology has been known. Normally, gas generators are classified according to how fuel and air are fed in relation to one another, updraft gasifiers and downdraft gasifiers. There are also other gasification principles, e.g. fluidised bed gasification.

Commercial gasifiers are available in a range of size and types, and can be run on a variety of fuels, including wood, charcoal, coconut shells and rice husks. Power output is determined by the economic supply of biomass, which is limited to a maximum of 80 MW_e in most cases.

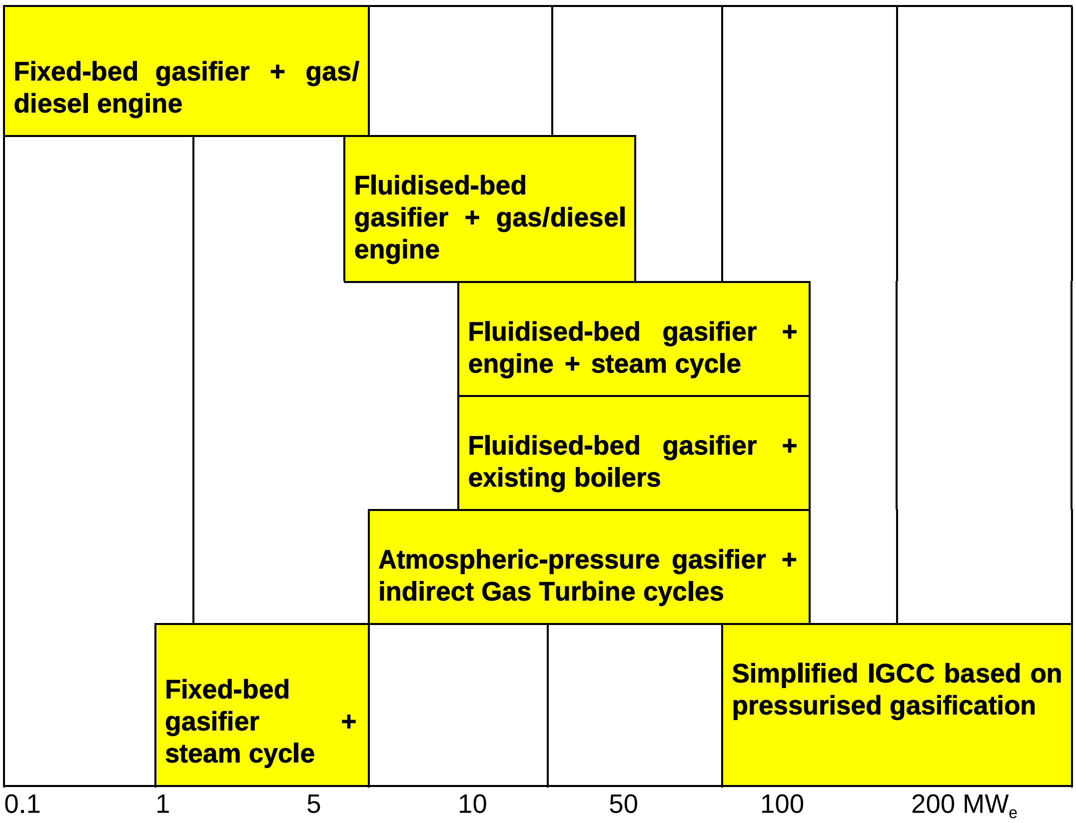


Figure 2.3 - Gasification technologies for solid fuels suitable for use in power plants of different size classes. Source: VTT Energy.

Atmospheric CFB gasification technology of dried biomass is commercial technology. The product gas can be easily burned under ambient conditions. However, biomass must be dried in a special dryer, which represents a considerable capital cost. Gasification of wet biomass represents no technological problems. However, gasification in stand-alone boilers without support fuel produces gas of very low heat value that is difficult to burn. A solution is to lead the hot gas directly into a coal- or oil-fired large-scale boiler, enabling co-combustion of the lean gas in the gas burner. A fuel feeding system has been developed for adjusting the moisture content of the fuel mixture and so the heat value of the gas. This eliminates the need of an expensive fuel dryer.

Integrated gasification combined cycles (IGCC) have been developed and demonstrated for power generation using fossil fuel. The main features are the possibility of cleaning the gas produced from impurities, such as particulates, sulphur, etc. under the pressure before the gas enters the combustor of the gas turbine, and also the relatively high electrical efficiency. Higher efficiencies also mean relatively lower emissions. Biomass gasification is the latest generation of biomass energy conversion processes, and is being used at a scale of up to 50 MW_e to improve the efficiency, and to reduce the investment costs of biomass electricity generation through the use of gas turbine technology. High efficiencies (up to about 50%) are achievable using combined-cycle gas turbine systems, where waste heat from the gas turbine is recovered to produce steam for use in a steam turbine. Economic studies show that biomass gasification plants can be as economical as conventional coal-fired plants. However gas cleanup to an acceptable standard remains the major challenge yet to be overcome. The first gasification combined-cycle power plant in the world is a 6 MW facility at Värnamo, Sweden, which is fuelled by wood residues.

Biomass pyrolysis technology offers a novel method of converting solid biomass to a liquid product that can easily be transported, stored and utilised for electricity production by diesel engines and gas turbines. Pyrolysis oil is produced from biomass in pyrolysis oil production unit. After that pyrolysis oil can be transported to diesel power plant and utilised in electricity production. A modern diesel power plant has an efficiency of 40 – 44% with a high power to heat ratio. Pyrolysis oil can be produced by high energy efficiency, typically 65 – 90 % from wet wood chips. The challenge of today is to understand and improve the properties of pyrolysis oils in order to reach a 12-month storage time without any changes in homogeneity of pyrolysis oils. Reliable operation of diesel power plants has to be demonstrated. As soon as these problems have been solved, biomass pyrolysis technologies will offer new attractive bioenergy market opportunities where a huge potential can be reached in converting existing petroleum-fired boilers, 0.1 – 10 MW to bio-oils and followed by combined heat and power production with high-efficiency diesel power plants in 0.1 – 10 MW scale.

Stirling engine is a promising alternative in small-scale electricity production. Potential advantages related to Stirling engines are their high efficiency also in small scale, and their relative insensitivity towards impurities in flue gas, if special designed Stirling engines are used. A market has been defined in Austria and Denmark for these engines. Heating stations (more than 2500 in Austria) using biomass could cover their own internal power consumption in co-generation with a Stirling engine. Typical electric output for Stirling engine is 30 – 60 kW_e. In the Stirling engine there is no combustible gaseous fuel mixture in the engine, but only a gas as the working fluid that is heated and cooled by turns. The heat for the Stirling engine working fluid comes from combustion process. The transfer of the heat from combustion process to the engine working fluid takes place by means of a heat exchanger.

The results from the tests show that the efficiency calculated as shaft power compared to the heat transferred into the hot heat exchanger without losses in the burner is approximately 35 % at full load. The efficiency of the electricity production is 19 % when water content of wood chips is 40 %. When the Stirling process is utilised in CHP total efficiency is about 87 %. Typically power output is less than 50 kW_e.

In the ORC (*Organic Rankine Cycle*) a heat source vaporises organic fluid in a vaporiser, and the vaporised fluid expands in the turbine of a high speed turbo alternator. The expanded vapour is then condensed in a condenser and pumped back to the pressurised vaporiser. The condenser is cooled by a suitable coolant, e.g. in cogeneration by the returning heating water. In Finland technology development is concentrated on high speed technology with high efficiency (power to heat ratio 0.35). The typical output of the plant is 350 – 3 500 kW_e. ORC process is suitable for the electricity production from solid, liquid or gaseous fuels, as well as from waste heat. There is so far no commercial ORC plant build by biomass.

Anaerobic digestion is the decomposition of wet and green biomass through bacterial action in the absence of oxygen to produces a mixed gas output of methane and carbon dioxide known as biogas. In Nordic countries mainly in Denmark and Sweden co-digestion of organic wastes and animal manure types, have been developed and there are 20 large-scale co-digestion installations in Denmark. Anaerobic digestion of especially wet biomass and waste is a commercially proven technology. In Europe alone, it is estimated that at least 1700 plants (including small-scale units) are currently in operation. These plants have limited power generating capacity (< 200 kW_e). The reason is that most emphasis placed on processing waste streams, while electric power is considered as a useful by-product, lowering processing tariffs by the sales of power delivered to the grid. Processing of wet biomass in anaerobic digestion system avoids expensive drying for thermal conversion processes.

Biogas can also be used in internal combustion engines involving as well as the Otto (spark ignition), the Diesel (compressed ignition) or the Sabathe (mixed) cycles. These engines can be used for mechanical power, or for electrical power generation. When using biogas, cogeneration has proven energy efficiency. The waste heat (up to 70 %) generated by the engine is recovered as hot water.

CHP plants are built for financial gain. Cogeneration must be cheaper than the acquisition of corresponding amounts of power and heat with other methods. The profitability of different alternatives must be assessed for the whole life expectancy of a power plant. It is normally more costly to build but cheaper to operate a CHP plant than a plant employing other production methods. The owner of the power plant may consume the power and heat, or they may be sold to other customers.

The environmental protection costs of power plants affect the economy of a CHP plant and its alternatives. Finland imposes the same environmental requirements on CHP plants as on other power or heat production plants of a corresponding size.

Cogeneration usually requires larger investments than alternate power and heat production methods. The counterbalance is a smaller consumption of primary energy. Therefore, the production costs of CHP may be lower than those of other generation forms.

The economy of a biomass fired CHP plant and the profitability of the investment in the plant depends to a great extent on local conditions such as the heat consumers, the volume and permanence of the heat load, and the price of the available fuels.

The economic size limit has come down during the last 5 – 10 years due to the technological achievements and the fuel cost reduction. One example in Finland shows how the investment cost of a CHP plant has dropped to one third during the period of 1979 to 1991. The price of biomass fuels (mainly wood fuels) has reduced because of the improved wood fuel harvesting technology. The average price of wood fuel is in Finland 2.1 Euro/GJ.

In size scale of 6 MW_e with peak operating time of 4000 hours per year, investment aid is 10–20% makes the CHP electricity generation using solid biomass fuels economically feasible. The district heat production is valued according to an optional production method of district heat. The investment cost of a 3 MW_e CHP plant is at a level of 2000 Euro/kW_e, 6 MW_e of 1500 Euro/kW_e and for a 17 MW_e 1200 Euro/kW_e. Thanks to low fuel price of industrial wood residues and the long annual operating time, the price of electricity generated at CHP plants in the forest industry can very profitable in Finland.

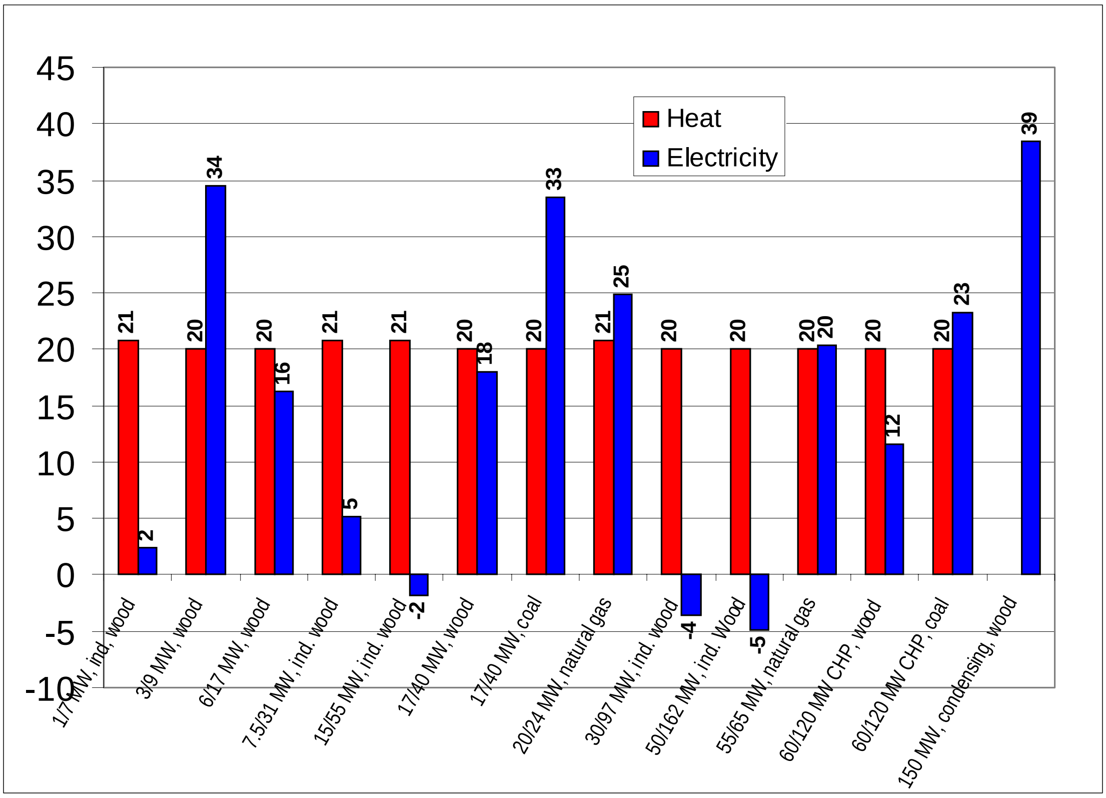


Figure 2.4 - Production costs of electricity and heat in Finland in different CHP plants in 1999 (Euro/MWh).

In small scale (2 MW_e) the systems compared were:

- the Rankine steam boiler power plant
- the gas engine power plant using gasification fuel gas. The gasifier and the engine are integrated.
- the diesel power plant using fast pyrolysis liquid as a fuel. Liquid production and the power plant are de-coupled.

Overall efficiencies for these systems are: the Rankine cycle 17.5%, gasification - gas engine 23.9%, and pyrolysis - diesel engine 24.7%. Potential improved efficiencies for the three technologies are 23, 34, and 31.5%, respectively. Estimated specific investment costs for the base power plants are 2 100, 2 100 - 3 800 and 3 300 Euro/kW_e, respectively.

It is shown that the Rankine cycle is superior compared to the gasification gas engine and pyrolysis diesel engine with current cost data. Increasing fuel cost 50% from the base value Euro 2.1/GJ improves the competitiveness of new concepts, but the Rankine is continuously more economic over the whole annual operation time. At high fuel costs, the difference between the diesel and the Rankine is negligible below 4 000 h/a. In a very long-term operation time, the gas engine is not much more expensive than the Rankine power plant. Differences between the alternatives are fairly small over the whole range, where improvements for technologies are assumed valid. The range of variation with the Rankine and the least-cost new cycle is about 10%, which is not a significant difference within the accuracy of the study. It is shown that cogeneration improves the economics of small-scale power production considerably. The Rankine cycle remains as the least-cost option in all cases studied.

It is concluded that for the new power plant technologies to be competitive compared to the Rankine cycle, especially capital costs have to be reduced. Without such reductions it will be hard to compete with the Rankine cycle in a small scale either in power-only or cogeneration mode of operation.

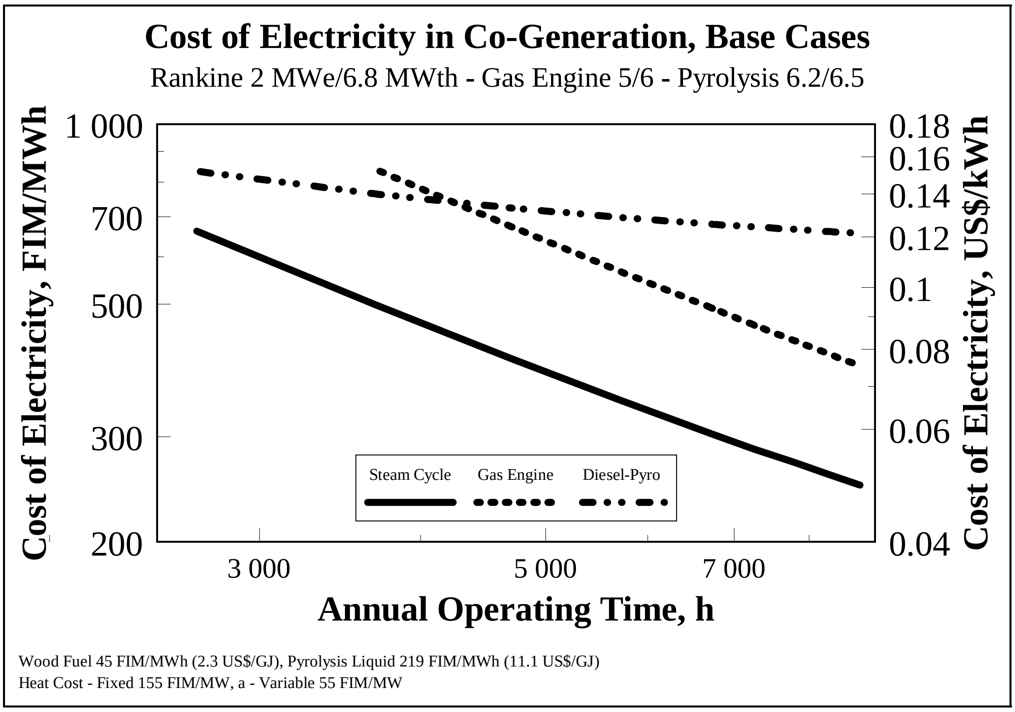


Figure 2.5 - The three technologies compared in small scale cogeneration (1 US$ = 0.91 EUR).

In size scale of 480 kW_e/5 MW with peak operating time of 6850 hours per year the electricity production costs of ORC process using biomass are 27.5 EUR/MWh. Investment costs for electricity generation components in ORC plant is 600 000 EUR.

Conclusions

The potential for biomass cogeneration in Europe is large. The technologies are already economic, but only in the right conditions. These conditions include:

- heat and power requirements match the outputs from a biomass cogeneration plant
- biomass resource (e.g. availability of industrial wood residues, introduction of energy crops in agriculture)
- technology developments continue

Once the technological, economic and policy developments have been sorted, the widespread installation of biomass cogeneration in Europe can be achieved.

2.2.3 Cogeneration for Cooling

Cogeneration is the simultaneous production of heat and electricity, both of which are used. Less well known is the simultaneous production of electricity, heat and/or cooling, especially in Europe.

There are different ways of coupling a cogeneration system with a chiller, either by compression or by absorption.

Compression water chillers

In this cycle one fluid is compressed, condense and evaporated in a close system. Chiller efficiency is analysed through a ratio called the coefficient performance (COP). The ratio represents thermal energy output versus energy input.

Different compression solutions are available depending on the use of the chiller: reciprocating compressor, screw compressor and centrifugal compressor, which are the most commonly used for district cooling.

Due to the low operation and capital cost, electric drivers are a frequent choice for driving compression chillers, but there are other alternatives, such as steam turbine, direct combustion engines or gas turbines. Maintenance cost can be different from one another.

Absorption chillers

Absorption chillers use heat as primary energy to produce cooling. They can use the heat of steam, hot water or direct gas combustion, depending on the technologies. They can be integrated in a steam, hot water or gas district network. This is the main district cooling policy in Germany and Japan.

The can also be used in industrial processes. Their application is optimal when low grade heat is available, under the conditions where a steam turbine can not be driven.

With absorption chillers the refrigerant is absorbed fluid under low evaporation pressure. Two fluids are necessary:

- The refrigerant, which should evaporate and condense;
- The absorbent, which should absorb refrigerant vapour. It is usually lithium bromide or ammonia. The second produces lower temperatures, but has toxic effects.

Operation and maintenance

When taking into consideration their related equipment, cost seem to be almost the same for absorption and compression chillers. Maintenance is reduced in absorption chillers because there are few moving parts and their operating life is typically 30 years.

Start up and shut down take longer time with absorption than with compression chillers, although it has the advantage that the COP can be easily regulated.

Investment and operating cost

Capital cost for absorption chillers are much higher than for compression chillers. Site-specific factor such as additional cost to upgrade the electrical service can change the comparative capital costs. Besides, electricity prices are generally high in summer, which encourages the absorption chiller solution. Absorption chillers are by far the most important part if the Japanese air conditioning market as well as individual chillers in district cooling systems.

Adsorption chillers

In an adsorption chiller the refrigerant is absorbed by a solid hydroscopic material, like Silica-gel granules.

This type of chiller requires, as its primary energy source, a heat source with a temperature of 80 to 100°C (hot water) and can generate chilled water down to 5°C. The adsorption chiller rejects a high quantity of heat, which requires a expensive high capacity cooling system.

Ice-slurry

These systems are based on the circulation of a mixture of the cooling medium, generally water) with its ice crystals, at its melting temperature. Some systems exist in Japan, Korea, China, South Africa, Canada, Botswana and Denmark.

The technology is still in an experimental stage in many countries, although it has a large potential in district cooling systems. Significant progress is being made to reduce costs.

Production, design and integration of district cooling systems

Central chilled water production

This is mainly based on compression type water chillers, which have the highest COP. They are usually packaged units, maintenance is well organised and spare parts easily available.

Multiple chilled water production plants

Large networks may have several chilled water production plants. These plants can be chiller plants or thermal energy storage. With this design, reliability and flexibility of distribution are increased. This design may become a necessity when the cooling demand surpasses the cooling capacity in existing pipes at the outlet of the plant.

Series and parallel production

This design allows different stages in the chilling of the water. This technique has a power limit: when the load is two high all the flow required cannot pass only one chiller.

Integration of absorption chillers in cogeneration production

When producing electricity cogeneration uses the heat instead of wasting it. One way of using it is the integration of an absorption chiller.

Cogeneration technologies can be differentiated depending on the prime mover. Some possibilities are steam turbines, internal combustion engines or gas turbines.

Improvement of cogeneration energy efficiency

Direct exhaust heat recovery

In DCSs, two-stage absorption chillers are mainly used to get greater capacities. They have to be driven by high temperatures. They can accept the exhaust gases directly from a gas turbine, or internal combustion engine, into a specially designed heat exchanger to heat the lithium bromide solution.

It is possible to increase the cooling production available by enhancing the thermal quality/quantity of the exhaust gas stream, by using an auxiliary burner to raise the temperature and/or hot gas to the chiller/heater.

The leaving chilled water temperature from the chiller is regulated by controlling the flow of exhaust gas through the lithium bromide heat exchanger. Unused hot exhaust gas can be diverted into another heat recovery process, or to the atmosphere.

Turbine inlet air cooling

Gas turbine performances are decreased when the inlet combustion air temperature rises. The turbine capacity can be penalised by 15 to 18% (or more) in elevated air temperatures. The use of cooling from the absorption chiller to cool the combustion air prevents high inlet temperatures. It will improve the summer capacity of the gas turbine.

Integration of cooling substations in district heating systems

A district heating system (DHS) can supply a «cold substation», in which absorption chillers produce chilled water to supply secondary systems.

During summer DHSs have a low load. Chilled water production is a good way to improve their efficiency. Two main solutions are available: integration of one-stage absorption chiller in a hot water network with a temperature around 100°C or integration of two-stage chillers in a steam or super-heated water network.

Cooling applications

Basically, cooling can be integrated in all cogeneration applications, district cooling, industry (for instance food industry lacks sources of cold water during summer) and individual buildings.

Trigeneration is the conversion of a single fuel source into three energy products: electricity, steam or hot water and chilled water, with lower pollution and higher efficiency than producing the three products separately.

District cooling is the application that presents more challenges, since it faces the challenges of district heating (high capital cost among others) and the challenges of being a new technology. However the technology is known and used in Japan and the United States. It is less well known in Europe, but new opportunities may arise from the fact that the heating demand presents a downward trend, while the demand for comfort and cooling is rising, together with the electricity demand. The problem is that countries where the cooling demand is higher lack district heating infrastructure.

District cooling development

As just mentioned, the technology has developed very differently around the world. The degree of development does not coincide with the degree of cogeneration development in a country, not even with the degree of district heating CHP development.

The most important factors affecting its development are:

- The energy policy and regulatory framework in a country;
- The tradition of developing district energy as a public utility or a private initiative;
- The energy prices and the economical pre-conditions for investment;

- The climate of a country.

Conclusions

- Cogeneration is a well-known technology, but it is less well known when produced in combination with cooling, especially in Europe. The simultaneous production of power, heat and cooling is called trigeneration;
- There are different ways of producing trigeneration, the best-known ways being absorption and compression;
- Compression uses electricity to produce the cool, while absorption uses the heat, which makes this application more optimal from an efficiency point of view;
- Although installing trigeneration instead of cogeneration does increase the cost, it seems that the problem for its development is one of awareness rather than one of costs –unless there is a situation of extremely low electricity prices and high gas prices such as currently. The proof is that district cooling (the application facing most challenges) has developed in the USA under market conditions;
- A key factor for the development of district cooling will be utilities starting to consider it as a serious business option. In the future, with liberalised energy markets, it can become a way of ensuring captive customers. This is what happened in the USA.

3 MARKET SCENARIOS

The future is uncertain, and may take one of many paths. Often, factors can be grouped into likely similar or likely outcomes, or scenarios. Scenarios reduce the number of possible futures to a manageable set of variables that can be modelled. The focus of a scenario is the individual decision of a site or host to either develop a long-term relationship with an Energy Services Company to provide CHP to a site, or to invest in CHP to provide heat and electricity to their own site or to residents or tenants.

The decision by any given host to invest in CHP is affected principally by:

- Electricity prices
- Fuel (particularly gas) prices
- The cost of capital
- The cost of equipment
- The efficiency of that equipment in converting fuel into the high value commodity (electricity) and to a lesser extent, the efficiency of conversion into a lower value commodity (heat).

These factors are first outlined. However, policy at either the national or European level can influence the cost or value, or perceived cost or value of any of these commodities, to an individual host. The following issues

- Accession and the extent to which liberalisation and environment are required as part of the energy market framework before accession can occur. Whilst this clearly mainly affects those countries seeking accession, the effect in those countries – who have significant existing community heating- is dramatic.
- The balance of liberalisation and environment in energy policy. Liberalisation is a key element of ensuring secure and diverse energy sources. But increasingly efficient use of resources is seen to contribute to security of supply. And Environment is focused on fostering sustainability. It has long been the case that Security, Diversity and Sustainability are the watchwords of Energy Policy
- Within these frameworks, there are a number of specific issues that affect CHP. Fiscal instruments include energy or carbon taxation, and the internalisation of external costs. Regulatory issues include the regulation of the cost of connection, the use of the distribution system, and the pricing of time of use and imbalances.

Given these tensions in policy, one can see a number of possible futures:

- Present Policies - current policies in the energy sector continue, particularly those that affect cogeneration, including changes expected to happen. Energy sector liberalisation in Europe is expected to be complete by 2010. Technological developments will be evolutionary, as opposed to revolutionary.
- Heightened Environmental Awareness - based upon Present Policies, but with additional benefits for "green" technologies. This includes the internalisation of the external benefits of cogeneration through the introduction of a carbon tax and faster technological developments.
- Deregulated Liberalisation - liberalisation of European energy markets continues, but with no incentive for smaller scale decentralised generation capacity. The electricity market is expected to be dominated by only a few centralised generators, who strongly influence electricity prices. The net result is that

cogeneration could become non-competitive, with plant being closed, leading to a reduction in cogeneration output. This is the worst case scenario.

- In a Post-Kyoto world, the benefits of cogeneration are fully internalised into the cost of the technology. Micro cogeneration becomes technically and economically feasible and fuel cell cogeneration becomes a possibility with the increased amount of investment flowing into "cleaner" technologies in a world tied to the Kyoto Protocol targets. The flexible mechanisms, such as emissions trading and Joint Implementation, provide a new source of finance for cogeneration. Economic and energy policies are focused on decentralised generation and Europe achieves major environmental benefits as a result of the increased efficiency of its generation mix. This is the best case scenario.

Table 3.1 illustrates the type of scheme that sites with a heat demand of 0.2 MW_e (such as a hotel), 1 MW_e (hospital), 10 MW_e (small paper mill) and 100 MW_e (chemical works) might build under each of these scenarios. Once these schemes are aggregated up to the total heat demand for one country or across the EU, it serves to show how the policy framework, feeding through into electricity prices, fuel prices, the cost of capital and equipment, can dramatically affect the build-rate of CHP: the change in capacity of the Post Kyoto scenario could be as much as an order of magnitude more than Deregulated Liberalisation. The succeeding parts of this section unpack some of the detail of these scenarios.

Table 3.1 - Typical technologies under each scenario

Site Conditions	**Present policy**	**Heightened Environmental Awareness**	**Post Kyoto (Best Case)**	**Deregulated Liberalisation (worst case)**
Summary	All agreed policy is in the baseline including Kyoto-level burden sharing.	More demanding targets with strong EU-level policy.	Decentralised market with internalisation of external costs.	Liberalisation does not succeed in a number of member states, i.e. remaining significant market domination and little regulation.
0.2 MW heat (seasonal heat demand), 0.2 MW electric	Small proportion of sites may build 100 kW schemes	Larger proportion of sites may build 100 kW schemes	High proportion of sites build 100 kW schemes	No sites build 0.2 MW_e schemes. New gas-fired heat-only boilers installed.
1MW heat (seasonal heat demand), 1 MW_e electric	Some sites build 200-400 kW schemes sized to base heat load	Larger proportion of sites build 200-400 kW schemes sized to base heat loads	High proportion of sites build 200-400 kW schemes sized to base heat loads	Few sites build schemes. New gas-fired heat-only boilers installed.
10 MW heat (stable for 7000 hours pa.), 10 MW_e electric	Schemes sized on base load electrical demands to avoid export, - circa 2-4 MW schemes. Existing 1-2 MW_e ST schemes retained.	Larger proportion of sites build 4-5 MW schemes (gas engine or GT depending on heat requirements) sized to heat loads	High proportion of sites build 10 MW CCGT schemes sized to base heat loads	Few sites build schemes. New gas-fired heat-only boilers installed.
100 MW heat (stable for 8000 hours p.a.), 10 MW electric	Schemes sized on base load electrical demands Existing 10 MW_e steam turbine schemes retained.	Existing ST schemes replaced with 10 MWe gas turbines and significant supplementary firing. Scheme sized to avoid electrical export	Existing ST schemes replaced with 100 MW_e CCGT CHP, sized to heat load. Smaller adjacent sites served by single larger CHP scheme	Some existing schemes remain, few upgraded, and some retired and replaced with gas heat-only boilers.

3.1 MARKET FACTORS

Baseline gas and electricity prices have been taken from European Commission figures[9]. Electricity and gas prices for other scenarios (Heightened Environmental Awareness and Post Kyoto) depart from these and take into account a carbon tax, imposed at regional level, appropriate pricing of export electricity given use of system charges, etc (table 3.2).

The cost of capital is assumed to be lowest in the Post Kyoto scenario given that returns from schemes will be most secure.

Equipment prices are expected to fall from current levels (table 3.3) if sales volumes increase. This will make more schemes cost effective, and there will be something of a snowball effect. This is hard to model directly. However, micro-schemes (below 15 kW_e) are expected to decline by 35-65% by 2020, depending on uptake, and large schemes (>50 MW_e) may decline by a third by 2020 (table 3.4)

Table 3.2 - The effects on gas and Gas and Electricity Prices of different scenarios

	Present policy	**Heightened Environmental Awareness**	**Post Kyoto (Best Case)**	**Deregulated Liberalisation (worst case)**
Electricity prices	Base case (X Euro/kWh in 2010, and Y in 2020)	additional X% over base case in 2010, and Y in 2020	additional X% over base case in 2010, and Y in 2020	additional X% over base case in 2010, and Y in 2020
Gas prices	Base case (X Euro/therm in 2010 and Y in 2020)	additional X% over base case in 2010, and Y in 2020	additional X% over base case in 2010, and Y in 2020	additional X% over base case in 2010, and Y in 2020
The cost of capital	Base case (X % in 2010 and Y in 2020)		Low and stable interest rates allows long payback period	High or unstable interest rates requires short payback period

Table 3.3 - Current Equipment prices (Euro/kW_e)

Sector	Plant size	Coal + products	Gas	Heavy fuel oil	Light fuel oil	Biomass	Wastes	Biogas
Domestic	< 15 kW_e		3000		4000			3750
Commercial	15-100 kW_e		1200		1200	2500	2750	1500
	100kW_e-1MW_e		1000		1000	2500	2750	1250
	1-5 MW_e	2000	800	1800	800	2000	2200	1000
Industry	1-5 MW_e	2000	800	1800	800	2000	2200	1000
	5-50 MW_e	1800	750	1620	750	1800	1980	938
	> 50 MW_e	1500	600	1350	600	1500	1650	750

Table 3.4 - Equipment prices under different scenarios

	Present Policies	**Heightened Environmental Awareness**	**Post Kyoto (Best Case)**	**Deregulated Liberalisation (worst case)**
2010 <15 kW_e	65%	55%	40%	100%
>50 kW_e	85%	85%	85%	100%
Average	84%	83%	80%	100%
2020 <15 kW_e	45%	45%	35%	90%
>50 kW_e	80%	80%	67%	100%
Average	80%	80%	71%	97%

[9] European Union Energy Outlook to 2020, Shared Analysis Project, November 1999

3.2 TECHNOLOGY FACTORS

The technologies and fuels outlined in table 3.5 are considered the most likely combinations in any given application currently. By 2020, Stirling Engines and Fuel Cells are expected to dominate domestic applications (predominantly gas-fired, but with some fuel oil and biogas fired units). Biomass and waste fired schemes are expected to have developed into gas turbines based on gasification or pyrolysis technology. Developments in individual technologies are outlined in table 3.6.

Table 3.5 - Current Technologies

Sector	Plant size	Coal + products	Gas	Heavy fuel oil	Light fuel oil	Biomass	Wastes	Biogas
Domestic	< 15 kW_e		GE		GE			GE
Commercial	15-100 kW_e		GE		GE	ST	ST	GE
	$100kW_e$-$1MW_e$		GE		GE	ST	ST	GE
	1-5 MW_e	ST	GT/GE	ST	GT/GE	ST	ST	GT/GE
Industry	1-5 MW_e	ST	GT/GE	ST	GT/GE	ST	ST	GT/GE
	5-50 MW_e	ST	OCGT	ST	OCGT	ST	ST	OCGT
	> 50 MW_e	ST	CCGT	ST	CCGT	ST	ST	CCGT

Notes: CCGT: Combined cycle gas turbine
GE: Gas engine
GT: Gas turbine
OCGT: Open cycle gas turbine
ST: Steam turbine

Table 3.6 - Technological developments to 2020 under different scenarios

	Present policies	**Heightened Environmental Awareness**	**Post Kyoto (Best Case)**	**Deregulated Liberalisation (worst case)**
Micro CHP	Comes to market in 2008. Never achieves lift-off from niche market	Comes to market in 2004. Achieves lift-off in key national markets	Comes to market in 2003 as a result of technology push. Achieves technological flip with significant market penetration.	Micro-CHP doesn't happen.
Fuel Cells	Fuel cells hit the car market and some other niches in 2010.	Fuel cells hit the car market in 2006.	Fuel cells achieve a technological flip in 2004.	Fuel cells used in distributed generation applications but with no heat recovery.
Combined cycle gas turbine (CCGT) efficiency	CCGT achieve >60% in 2010	CCGT achieve >60% electrical efficiency in 2010, schemes with heat leak built	CCGT achieve >60% electrical efficiency in 2010, schemes sized appropriately to the heat load	CCGT achieve >60% electrical efficiency in 2004, and used in electricity-only applications, closing off specific application for CHP for 20 years.
Prime-mover evolution	Incremental efficiency improvements in gas turbines and reciprocating engines	Incremental efficiency improvements in gas turbines and reciprocating engines	Incremental efficiency improvements in gas turbines and reciprocating engines	

3.3 POLICY SCENARIOS

Whilst electricity and gas prices, the cost of capital or the cost of equipment have a direct bearing on the decision to invest, Government, either at the national level or the EU level, can have an effect on these factors indirectly through changes in policy. Section 2.1.3 outlines these policy options in more detail. This section shows, in a qualitative sense, the relationship between any given policy and each 'world view' or scenario.

3.3.1 Accession

Key amongst these are the rate at which non-EU members are allowed to join the EU, and the extent to which they need to achieve liberalised markets or impose regulatory frameworks including competition and environmental regulation.

Table 3.7 - Accession under different scenarios

	Present policies	Heightened Environmental Awareness	Post Kyoto (Best Case)	Deregulated Liberalisation (worst case)
Accession	Accession is slow, and threshold requirements for market liberalisation and regulation, including environmental objectives is weak	Accession with stricter environmental control requires some refurbishment of existing plant	Accession requires preservation, refurbishment and expansion of existing District Heating network, maintaining around 50% of electricity generation from CHP	Accession destroys the existing District Heating Infrastructure.

3.3.2 Security and Diversity

Security Diversity and sustainability are key words of energy policy. Security and diversity have been most widely promoted in recent years by opening markets (table 3.8). In recent communications (for example the UK Governments 1998 Energy White Paper[10], mirrored in Commission communications), efficient use of energy as a way of both reducing dependency on imported fuels, and improving sustainability, has become more high profile.

Table 3.8 - Security and Diversity through liberalisation under different scenarios

	Present Policies	Heightened Environmental Awareness	Post Kyoto (Best Case)	Deregulated Liberalisation (worst case)
Security of supply	No change in the aim of opening up markets	Opening up of markets is accompanied by regulation which preserves the use of premium fuels in preferred (high efficiency) applications (e.g. consent to burn gas in power generation required, and	Energy efficiency to reduce dependence on imports becomes as important as liberalising markets	Centralisation and development of nuclear limits gas use

[10] HMSO (1998) Conclusions of the Review of Energy Sources for Power Generation, CM 4071

		depends on CHP as in UK)		
Liberalisation of Gas	Liberalisation aimed for in10 years	Liberalisation aimed for in 2004	Liberalisation aimed for in 2004, with safeguards for CHP	Liberalisation Fails with remaining significant market domination
Regulation of Gas	Regulation is focused on competition to drive down unit price	Regulation includes social and environmental obligations secondary to price (as in UK)	Primary purpose of regulation is social and environmental obligations and price regulation is secondary	There is no regulation of competition or of price of natural monopolies (such as pipelines).
Liberalisation of electricity	Liberalisation aimed for in10 years	Liberalisation aimed for in 2004	Liberalisation aimed for in 2004, with safeguards for CHP	Liberalisation Fails with remaining significant market domination
Regulation of electricity	Regulation is focused on competition to drive down unit price	Regulation includes social and environmental obligations secondary to price (as in UK)	Primary purpose of regulation is social and environmental obligations and price regulation is secondary	There is no regulation of competition or of price of natural monopolies (such as pipelines).
Unbundling • of Generation and Transmission • of Generation and Supply • of Distribution and Supply	Unbundling of electricity generation distribution and supply is weak, and variable in different countries	Unbundling is fast-tracked	Unbundling means full legal and physical separation	Unbundling doesn't happen, indeed there is more vertical reintegration through buy-outs
Opportunity for new market entrants		Consents policy requires that use of heat is considered by developers	Consents is dependent on	
Decentralisation	Range of prices and rules limit access for Cogen. Prices and rules not transparent Prices include connection to and use of system,. Rules for network connection prohibitive (e.g. requiring export at low voltage plus step-up transformer, or	Gradual re-examination of rules and pricing connections and use of system in some countries	Wholesale re-examination of rules and pricing for connection to and use of system to encourage connection of embedded generation in a free market with cost-reflective pricing. Embedded generation may be paid for connecting where it avoids network upgrade.	Centralised system with continued barriers to connection of embedded generation.
Gas Network	Rules in some		CHP given priority	

[11] Tariff Access means that a scheme cannot take advantage of competitive market for gas, and has to pay the same rate as smaller consumers. In some countries, a 4.5 MW_e Gas turbine electricity –only scheme would be able to buy gas on the open

Access (extension of network, pricing and rules)	countries requiring purchase of gas at low pressure requiring gas compressor. Tariff access11 for Small scale CHP phased out in 2007		access to gas in the competitive market. Electricity-only schemes required to pay tariff rates. Gas prices are not dependent on size (either through regulation, or through brokering arrangements)	
Electrical Network Access (extension of network, pricing and rules)			Embedded generation given priority access and priority despatch in central despatch systems. Electricity prices are not dependent on size (either through regulation, or through brokering arrangements) Embedded generation is paid to connect rather costs to connect. Requires both unbundling and improved transparency.	
Value of exports	Postage stamp tariffs, i.e. the wholesale price minus an administration charge	Appropriate premium price for export	Reflective costing means embedded generation is 50% cheaper to transport	
Cost of importing (back-up and top-up Electricity)			Value of exports much more closely related to price of imported electricity (kWh for kWh). Individual or independent CHP operators have Purchasing Agency to secure favourable power export and back-up supply tariffs.	Trading arrangements which penalise unpredictable demands or generation
Asset management (stranded assets and congestion)				

market. The same scheme operating as CHP would need to buy gas at tariff prices. This is a significant disincentive to CHP (This is allowed under the Gas Directive, see A18.2 of SN4930/97)

3.3.3 Environmental Sustainability

Environmental Sustainability policy measures include reducing greenhouse gas emissions as well as reducing local pollutants such as particulates, SO_2 and NO_X emissions. Measures that improve the efficient use of energy, such as the proposal to require developers to examine options for CHP under the Large Combustion Plant Directive, contribute to security diversity and sustainability objectives.

Table 3.9 - Sustainability under different policy scenarios

	Present Policies	Heightened Environmental Awareness	Post Kyoto (Best Case)	Deregulated Liberalisation (worst case)
Carbon Emissions target reduction	6%	10%	20%, in line with the most demanding targets in individual countries	Fail to meet 6%
Pollution control	Weak	Accelerate uptake of CHP as Best Available Technology	No new non-CHP combustion plant	Significant new gas-fired electricity-only plant

3.3.4 Specific Cogen Policy Objectives

It is a reality that most policy which affects the uptake of Cogen is not developed specifically for Cogen. Most of the time, Cogen is seen as a marginal player on someone else's turf. A key requirement is to begin to look at policy through the other end of the telescope: to recognise embedded cogeneration and renewable generation as the norm, and lower efficiency electricity-only plant as the exception. Central to this objective is the establishment of Cogeneration as a legally recognised concept, and one that can be measured and defined in statute. It is only once it can be measured and defined that it can be given fiscal or regulatory benefit.

Table 3.10 - Framework measures to re-orient the market towards Cogen

Cogen targets	Some countries have National target, but targets generally aspirational	Targets generally indicative	Target-led policy	No targets
Cogen legislation	Cogen is not recognised in primary legislation in most countries		Co-ordinated policy, Cogen defined in legislation as preferred technology not the marginal technology	Cogen remains a marginal technology
Cogeneration obligation				
Certainty		Fast track Liberalisation with market fixes	Stable framework, consultative and transparent	Forever changing market regulation leading to near anarchy
Cogeneration using renewables	Weak renewables policy for electricity but not for heat, and with no specific recognition of the role for renewables fired CHP	Strong renewables policy for electricity but not for heat, and with no specific recognition of the role for renewables fired CHP	Renewables policy for heat and electricity supports CHP for all combustion-based renewable fuels	No renewables policy for either heat or for electricity

3.4 CONCLUSIONS

The two extreme scenarios – Post Kyoto (Best Case) and Deregulated Liberalisation (Worst Case) describe a virtuous circle and a vicious circle.

- In the virtuous circle, policy favours Cogeneration, and would tend to widen the cost differential between primary fuel and electricity through internalisation of external environmental costs, open market access to new entrants through reducing connection costs, use of system costs, and through reducing the benefits that accrue to portfolio players, for example through regulation. This increases the rate of return for Cogeneration, and makes capital cheaper. This increases uptake, and increasing uptake is likely to result in lower capital cost through economies of scale.
- In the vicious cycle, incumbent (and often portfolio) players retain a decisive market advantage. The costs of new market entry are high, and rates of return poor. The cost of capital increases, and because each Cogeneration is almost bespoke, there are no economies of scale and capital costs remain high.

The challenge is how to avoid the worst case in each member state, and across Europe as a whole.

4 COGENERATION FUTURE

Given the four scenarios outlined in the previous section, the future of cogeneration could move in a number of directions, ranging from positive to negative. This section presents the main modelling results and what the energy market for cogeneration may look like in the future. The results are presented in terms of:

- Penetration to 2020 - capacity growth to 2020
- Targets - is the EU doubling target achievable?
- New markets - micro-cogeneration analysis
- Fuelling and supply - dynamics of new cogeneration penetration
- The dividend - CO_2 emissions benefits from cogeneration

4.1 COGENERATION TO 2020

Total cogeneration

Cogeneration capacity for the 28 European countries covered in ***future*** **cogen** currently stands at just under 100 GW_e[12], and has the potential to increase to 174 GW_e by 2010 and 252 GW_e by 2020. However, as this is only possible in the best case Post Kyoto scenario, if the policy and decision-makers in the region do not support cogeneration in the near future, then the position could be very different. In the worst case Deregulated Liberalisation scenario, which is currently closest to reality, shows a very different picture. Over the next ten years, capacity in Europe is under threat of decreasing as more plant is decommissioned than installed. The recovery to 2000 levels is also not expected to occur until after 2015. Figures 4.1 and 4.2 show the potential market penetrations of cogeneration in the EU and CEE respectively. No graph is shown for the remaining three countries, owing to the relatively low penetrations in the group (3 GW_e by 2020).

Figure 4.1 - EU cogeneration capacity by scenario (GW_e)

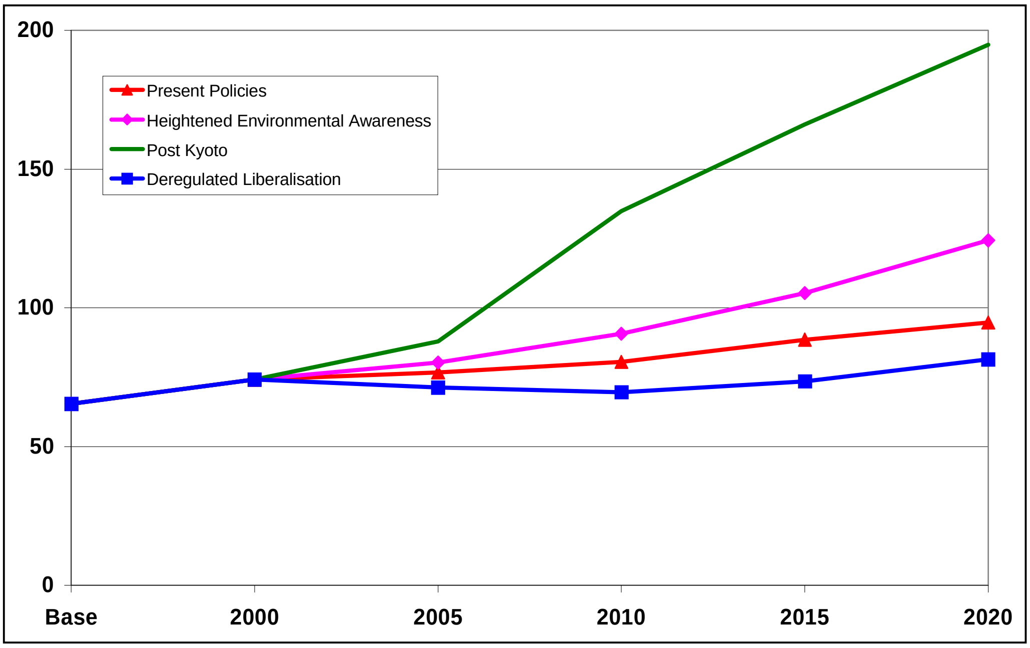
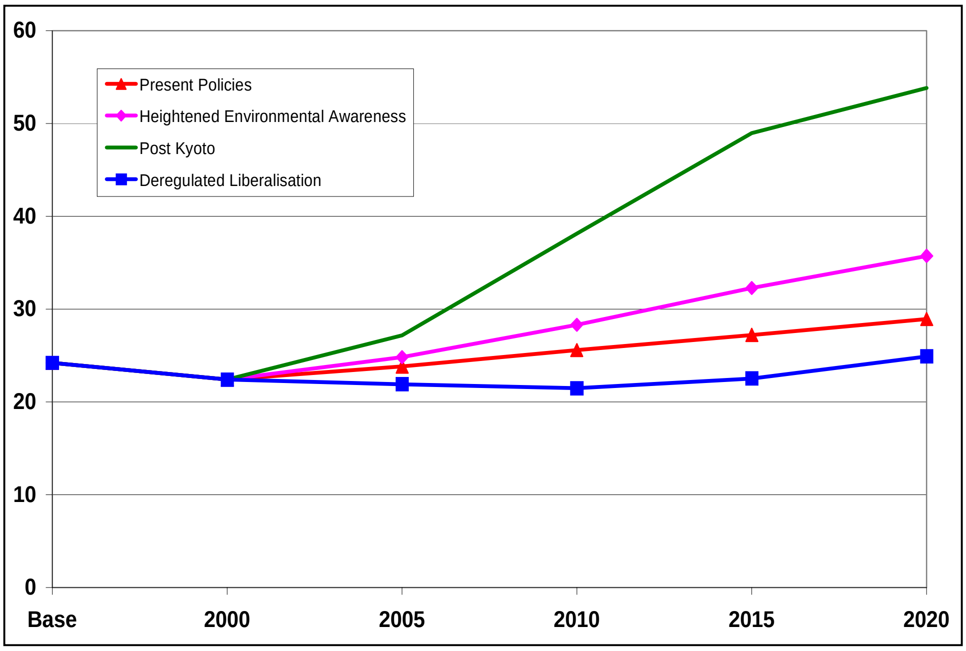


Figure 4.2 - CEE cogeneration capacity by scenario (GW_e)



In all countries in Europe, the current uncertainty and high risk in investing in cogeneration is having a negative effect on the long-term cogeneration potential. At the beginning of the project, the team expected to see higher penetrations by 2010 and 2020 in both the Higher Environmental Awareness and Post Kyoto scenarios. However, this has not happened and in some of the workshops, owing to the current situation, the experts believed both of these two scenarios were too optimistic. For the same reasons, the Present Policies scenario does not show much growth over the next twenty years. An increase of around 40% for the EU and 20% for the CEE from the base year to 2020 is very unremarkable. The growth levels in the three other countries over the same period are more than 200%, but from a low starting point.

National cogeneration penetrations are shown in tables 4.1 to 4.4, each table representing the outputs from each scenario. In Present Policies, penetration growth is marginal until after 2005. In Germany, penetration falls, while it is static in Portugal. After 2005, the rate of growth improves, but only at 1-2% per annum in the EU and around 1% per annum in the CEE. Growth in the "other" countries is higher at 3-5%, dominated by Switzerland.

[12] Source: Data network partners, based upon national statistics and other public domain information

Table 4.1 - Total Cogeneration - Present Policies scenario

	Capacity (MW_e)						Generation (GWh_e)					
	Base	**2000**	**2005**	**2010**	**2015**	**2020**	**Base**	**2000**	**2005**	**2010**	**2015**	**2020**
Austria	3651	3690	3779	3896	4037	4200	15196	15410	15709	16190	16631	17116
Belgium	1332	1341	1355	1361	1436	1661	6294	6330	6386	6409	6757	7615
Denmark	7982	7984	8037	8259	8590	8672	23835	23849	24115	25154	26992	27248
Finland	4040	4040	4298	4472	4574	4669	19756	19757	21378	22211	22689	23150
France	3530	5556	5763	5785	5809	5834	12450	21067	22769	22837	22912	22987
Germany	18751	18751	18632	20393	25369	26300	58317	58317	59171	66049	84292	86931
Greece	312	316	321	352	402	440	1467	1488	1512	1709	1994	2218
Ireland	115	117	180	270	372	443	623	632	990	1522	2164	2590
Italy	8047	10665	12271	12433	12774	13104	31653	42043	48426	48994	50317	51288
Luxembourg	71	71	87	123	154	177	291	291	366	515	649	737
Netherlands	7831	7873	8021	8190	8441	8897	39556	39780	40527	41369	42263	43564
Portugal	410	903	903	941	943	1149	2208	4528	4529	4738	4741	5824
Spain	2700	4546	4546	4437	4266	5244	14591	24553	24553	23962	23043	29731
Sweden	2837	3131	3132	3175	3260	3330	13449	14844	14854	15039	15432	15858
UK	3453	4632	5410	6459	8123	10588	15521	20692	24230	28898	36227	46296
Bulgaria	1264	1264	1304	1370	1655	2080	4807	4807	4950	5192	6279	7948
Czech Rep.	2737	2741	2794	2970	3074	3272	12192	12213	12420	13200	13640	14510
Estonia	434	434	465	497	604	669	1584	1584	1701	1827	2297	2541
Hungary	1221	1226	1261	1311	1356	1417	4987	5011	5156	5371	5537	5769
Latvia	586	587	595	641	772	980	1837	1842	1871	2036	2477	3128
Lithuania	831	831	833	861	932	1056	1720	1720	1726	1803	2035	2354
Poland	7021	7021	7031	7203	7409	7539	22548	22548	22586	23076	23637	24026
Romania	8550	6715	7823	8786	9260	9548	28953	22731	26447	29751	31300	32255
Slovakia	1268	1268	1309	1488	1639	1809	5318	5318	5479	6157	6707	7287
Slovenia	320	337	406	479	537	574	1465	1554	1924	2438	2912	3065
Cyprus	0	0	8	12	15	16	0	0	34	51	69	69
Norway	16	16	20	28	30	30	73	73	97	142	151	151
Switzerland	459	459	514	612	769	983	1869	1869	2087	2484	3084	3815
EU15 (GW_e)	**65**	**74**	**77**	**81**	**89**	**95**	**256**	**295**	**310**	**326**	**357**	**383**
CEE (GW_e)	**24**	**22**	**24**	**26**	**27**	**29**	**85**	**79**	**84**	**91**	**97**	**103**
Other (GW_e)	**0**	**0**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**3**	**3**	**4**
Total (GW_e)	**90**	**97**	**101**	**107**	**117**	**125**						

In the Heightened Environmental Awareness scenario, the implementation of policies that are more favourable to efficient technologies does have an effect, but it is not large. The other factors affecting cogeneration, such as uncertainty, attitude to risk and the market domination of the large utilities constrains the short-term effects of a 'greener' policy framework. In the longer term, cogeneration can expect to achieve some growth, but it is constrained to the 'traditional' cogeneration markets in the commercial and industrial sectors.

Annual growth is higher, at 2.5-3.5% in the EU and 2.5% in the CEE, but it still does not pick up until after 2005. The three other countries sustain annual growth levels of 7-8% over the whole period from the year 2000. The greatest proportional growth occurs in Ireland, Luxembourg, the UK, Bulgaria and Slovenia, Norway and Switzerland, where capacity is expected to double in the twenty year period from 2000. Cyprus also fits this criterion, but is excluded owing to its current zero capacity.

Table 4.2 - Total Cogeneration - Heightened Environmental Awareness scenario

	Capacity (MW_e)						Generation (GWh_e)					
	Base	**2000**	**2005**	**2010**	**2015**	**2020**	**Base**	**2000**	**2005**	**2010**	**2015**	**2020**
Austria	3651	3690	3879	4100	4440	5181	15196	15410	16102	16863	18075	20671
Belgium	1332	1341	1390	1707	1913	2214	6294	6330	6587	8012	9058	10023
Denmark	7982	7984	8102	8760	9172	9380	23835	23849	24414	28174	30004	30647
Finland	4040	4040	4331	4697	4891	5105	19756	19757	21731	23493	24464	25495
France	3530	5556	5819	6111	6467	7675	12450	21067	23370	23817	25231	29122
Germany	18751	18751	19779	23771	31011	36844	58317	58317	62387	76825	102859	120646
Greece	312	316	344	392	493	578	1467	1488	1643	1918	2420	3050
Ireland	115	117	231	442	577	694	623	632	1343	2627	3390	4118
Italy	8047	10665	13119	13870	15110	17917	31653	42043	51690	54291	58964	68824
Luxembourg	71	71	103	148	180	227	291	291	406	616	741	940
Netherlands	7831	7873	8285	8816	9974	11983	39556	39780	41950	44095	47483	53156
Portugal	410	903	912	1131	1431	1614	2208	4528	4598	5742	7344	8089
Spain	2700	4546	4545	4545	4545	5600	14591	24553	25972	25972	25972	33762
Sweden	2837	3131	3187	3346	3643	3954	13449	14844	15035	15703	17091	18535
UK	3453	4632	6259	8848	11458	15310	15521	20692	27985	39264	49958	63596
Bulgaria	1264	1264	1352	1745	2151	2820	4807	4807	5096	6453	7871	10296
Czech Rep.	2737	2741	2844	3104	3377	4072	12192	12213	12649	13795	14958	18247
Estonia	434	434	481	622	722	784	1584	1584	1762	2416	2786	3013
Hungary	1221	1226	1342	1429	1511	1627	4987	5011	5500	5874	6178	6604
Latvia	586	587	613	766	973	1154	1837	1842	1927	2460	3065	3608
Lithuania	831	831	848	910	1031	1202	1720	1720	1781	1969	2232	2677
Poland	7021	7021	7188	8302	9653	10250	22548	22548	23043	26523	30612	32344
Romania	8550	6715	8348	9261	10313	10963	28953	22731	28165	31246	34932	36988
Slovakia	1268	1268	1363	1646	1916	2200	5318	5318	5761	6675	8081	9102
Slovenia	320	337	449	545	641	678	1465	1554	2230	2649	3045	3204
Cyprus	0	0	14	20	24	26	0	0	62	93	111	120
Norway	16	16	20	30	52	118	73	73	101	157	289	722
Switzerland	459	459	627	955	1364	1868	1869	1869	2502	3779	5440	7347
EU15 (GW_e)	**65**	**74**	**80**	**91**	**105**	**124**	**256**	**295**	**325**	**368**	**423**	**492**
CEE (GW_e)	**24**	**22**	**25**	**28**	**32**	**36**	**85**	**79**	**88**	**100**	**114**	**126**
Other (GW_e)	**0**	**0**	**1**	**1**	**1**	**2**	**2**	**2**	**3**	**4**	**6**	**8**
Total (GW_e)	**90**	**97**	**106**	**120**	**139**	**162**						

It is only in the best practice scenario, Post Kyoto, that the potential for cogeneration is fully released. The implementation of climate change policy and the cultural shift towards decentralised electricity systems in Europe provide the two main catalysts to the developments in cogeneration. The former solves any economic issues associated with the energy market, while the latter removes the uncertainty in the market, which encourages developers and investors to install new that plant that would otherwise not have been commissioned. In this scenario, the technical and market barriers to domestic level micro cogeneration are removed, enabling a whole new market to be opened to the technology. Further information of the effect on micro cogeneration is include in section 4.3. Gas becomes the dominant technology in this scenario, as the majority of the growth over the Heightened Environmental Awareness scenario is fuelled by natural gas.

Significant growth is achieved, leaving to a doubling of cogeneration capacity to 2010 and a tripling ten years later.). Over the full modelling period, cogeneration capacity in Europe expands by a factor of three in the EU, 2.5 in the CEE countries, and by a factor of seven in the remaining three countries. Total European cogeneration capacity increases to 252 GW_e, generating almost 1000 TWh of electricity.

In CEE, any political reluctance to invest in gas technology is overcome and a large proportion of old fossil fuelled plant, predominantly coal, is replaced by efficient gas plant. This is achieved with little increase in heat output, as significantly better electricity to heat ratios are implemented with the gas technology.

Table 4.3 - Total Cogeneration - Post Kyoto scenario

	Capacity (MW_e)						Generation (GWh_e)					
	Base	**2000**	**2005**	**2010**	**2015**	**2020**	**Base**	**2000**	**2005**	**2010**	**2015**	**2020**
Austria	3651	3690	3978	5734	6547	7113	15196	15410	16457	23039	26186	28407
Belgium	1332	1341	1466	1799	2744	4356	6294	6330	6910	8305	11807	16196
Denmark	7982	7984	8349	10040	10792	11140	23835	23849	27634	35818	38158	39193
Finland	4040	4040	4735	5695	5855	5935	19756	19757	24246	28501	29312	29672
France	3530	5556	6029	7312	9583	14799	12450	21067	25658	31206	34079	43335
Germany	18751	18751	21133	42651	53299	59138	58317	58317	66419	150110	189554	213618
Greece	312	316	390	667	787	809	1467	1488	1990	3681	4553	4740
Ireland	115	117	323	703	952	1077	623	632	1914	4264	5828	6633
Italy	8047	10665	13682	17544	21455	26801	31653	42043	54032	68050	80287	93422
Luxembourg	71	71	120	188	268	314	291	291	483	751	1076	1271
Netherlands	7831	7873	9004	13028	16729	17832	39556	39780	45265	61674	70767	73580
Portugal	410	903	1816	2547	3078	3185	2208	4528	9300	12769	15321	15603
Spain	2700	4546	5306	6271	6324	9226	14591	24553	30848	36962	37325	58370
Sweden	2837	3131	3292	4767	5503	5862	13449	14844	15726	23411	26160	27514
UK	3453	4632	8275	15864	22177	27215	15521	20692	35989	65406	84716	100036
Bulgaria	1264	1264	1483	2348	3942	4644	4807	4807	5532	8622	14339	16685
Czech Rep.	2737	2741	3050	4091	5435	5769	12192	12213	13600	18327	24581	26037
Estonia	434	434	531	732	850	882	1584	1584	2020	2921	3733	3884
Hungary	1221	1226	1382	1819	2002	2101	4987	5011	5622	7357	8070	8435
Latvia	586	587	699	1023	1304	1408	1837	1842	2204	3272	4128	4478
Lithuania	831	831	942	1209	1566	1722	1720	1720	1993	2711	3640	4079
Poland	7021	7021	8363	14250	18894	21364	22548	22548	27172	45963	60274	67608
Romania	8550	6715	8818	10178	11890	12327	28953	22731	29894	34654	41154	42690
Slovakia	1268	1268	1411	1867	2322	2841	5318	5318	6094	8081	9907	12037
Slovenia	320	337	507	652	763	792	1465	1554	2239	3054	3915	4076
Cyprus	0	0	17	31	35	35	0	0	73	131	148	154
Norway	16	16	25	61	233	379	73	73	131	348	1449	2408
Switzerland	459	459	738	1786	2457	2921	1869	1869	2923	6993	9515	11191
EU15 (GW_e)	**65**	**74**	**88**	**135**	**166**	**195**	**256**	**295**	**363**	**554**	**655**	**752**
CEE (GW_e)	**24**	**22**	**27**	**38**	**49**	**54**	**85**	**79**	**96**	**135**	**174**	**190**
Other (GW_e)	**0**	**0**	**1**	**2**	**3**	**3**	**2**	**2**	**3**	**7**	**11**	**14**
Total (GW_e)	**90**	**97**	**116**	**175**	**218**	**252**						

The worst case scenario, Decentralised Liberalisation, sees very little growth in cogeneration until 2015. The economic incentives to install new cogeneration plant disappear and as current plant becomes economic, it is retired and is replaced by separate heat and electricity capacity. Once this occurs, the incentive and likelihood and cogeneration plant being re-applied, at these locations, is very small.

In almost all countries, cogeneration capacity decreases between 2000 and 2005, which continues in some to 2010. Growth over the whole period is low, averaging only 0.6% annual growth in Europe over the whole period of the study. The worst hit country is Germany, which loses more than 15% of its capacity in the five years between 2000 and 2005. As the country with the largest potential for new capacity in Europe (with growth of 40 GW in Post Kyoto), the effect of a negative market on German cogeneration is huge.

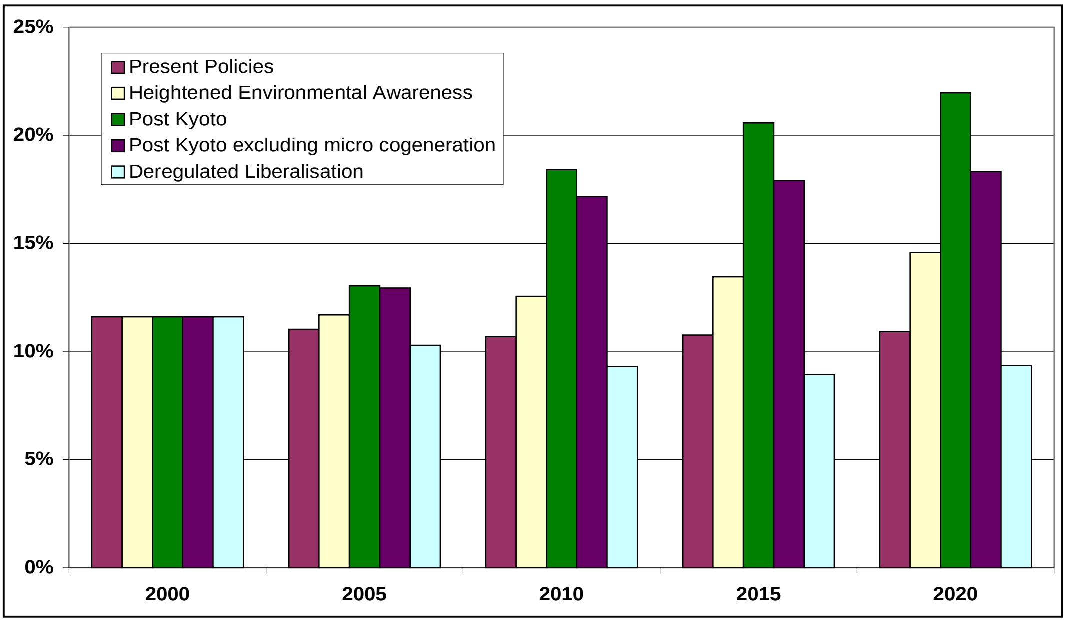
Table 4.4 - Total Cogeneration - Decentralised Liberalisation scenario

	Capacity (MW_e)						Generation (GWh_e)					
	Base	**2000**	**2005**	**2010**	**2015**	**2020**	**Base**	**2000**	**2005**	**2010**	**2015**	**2020**
Austria	3651	3690	3378	3141	3406	3809	15196	15410	12629	12039	13013	14708
Belgium	1332	1341	1105	1169	1300	1370	6294	6330	5349	5676	6321	6676
Denmark	7982	7984	7941	8042	8234	8405	23835	23849	23696	24265	25256	26075
Finland	4040	4040	4125	4197	4308	4375	19756	19757	20422	20796	21348	21700
France	3530	5556	5657	5657	5661	5684	12450	21067	21918	21918	21925	21961
Germany	18751	18751	16168	16716	18007	22147	58317	58317	52449	54252	60150	74516
Greece	312	316	272	280	288	328	1467	1488	1249	1293	1345	1566
Ireland	115	117	136	231	242	242	623	632	744	1306	1377	1377
Italy	8047	10665	11589	9461	10411	11158	31653	42043	45933	37361	41101	43970
Luxembourg	71	71	73	57	69	98	291	291	298	229	286	396
Netherlands	7831	7873	7478	7455	7678	7949	39556	39780	37713	37685	38787	40001
Portugal	410	903	903	903	915	951	2208	4528	4528	4528	4595	4784
Spain	2700	4546	4324	4007	3657	4104	14591	24553	23355	21644	19751	23032
Sweden	2837	3131	3141	3142	3142	3198	13449	14844	14902	14904	14904	15204
UK	3453	4632	4952	5144	6163	7538	15521	20692	21387	22196	26559	32484
Bulgaria	1264	1264	1244	1049	1151	1387	4807	4807	4750	4015	4407	5311
Czech Rep.	2737	2741	2428	2521	2702	2899	12192	12213	10760	11151	11907	12809
Estonia	434	434	438	453	487	582	1584	1584	1356	1413	1825	2285
Hungary	1221	1226	1230	1248	1263	1324	4987	5011	5035	5106	5166	5395
Latvia	586	587	567	491	387	488	1837	1842	1786	1557	1259	1577
Lithuania	831	831	749	598	649	969	1720	1720	1552	1253	1389	2121
Poland	7021	7021	6741	6426	6658	6919	22548	22548	21532	20262	20882	21822
Romania	8550	6715	7057	7467	8096	8700	28953	22731	23811	25341	27540	29637
Slovakia	1268	1268	1164	899	816	1282	5318	5318	4531	3495	3173	4968
Slovenia	320	337	313	327	339	373	1465	1554	1433	1492	1529	1635
Cyprus	0	0	5	7	9	11	0	0	23	34	39	49
Norway	16	16	16	16	16	16	73	73	73	73	73	73
Switzerland	459	459	455	346	412	566	1869	1869	1854	1400	1664	2242
EU15 (GW_e)	**65**	**74**	**71**	**70**	**73**	**81**	**256**	**295**	**287**	**280**	**297**	**328**
CEE (GW_e)	**24**	**22**	**22**	**21**	**23**	**25**	**85**	**79**	**77**	**75**	**79**	**88**
Other (GW_e)	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**2**	**2**	**2**	**2**	**2**
Total (GW_e)	**90**	**97**	**94**	**91**	**96**	**107**						

4.2 TARGETS

In 1997, the European Commission set a target to double cogeneration output as a proportion of electricity generation from 9% to 18% by 2010, which was contained in the Commission Communication on the promotion of CHP issued in that year[13]. A key objective of ***future* cogen** is to assess the likelihood of achieving this target. Figure 4.3 shows the EU proportions for the four scenarios. This shows that the target can only be achieved in the best case Post Kyoto scenario, which achieves 18.4% of total electricity generation in 2010. For both the Present Policies and Deregulated Liberalisation scenarios, the proportion of electricity even falls in the early years and in both cases, neither returns to the levels of cogeneration today. Heightened Environmental Awareness does achieve an increase, but it is insufficient to reach the target, even by 2020.

Figure 4.3 - EU cogeneration electricity output as a proportion of total electricity generation



There are two significant factors that are helping to decrease the levels of the graph in figure 4.3. Firstly, the electricity generation statistics for all scenarios are taken from the Conventional Wisdom scenario of the EU energy predictions[14]. For the two 'green' scenarios, one would expect the total energy demand and hence generation to be lower owing to energy saving management or improved energy intensity. This would have little effect on the penetration of cogeneration plant, but would lead to an increase in the electricity share from cogeneration and make the targets easier to attain. Secondly, the current sentiment in the cogeneration industry in Europe is negative. This is causing deep pessimism from many of the experts consulted during the project, which has resulted in lower total cogeneration penetration within the modelling process. If the policy and market framework is changed in the near future, the modelling process would produce more positive results and lead to an easier achievement of the EU cogeneration target.

Figure 4.2 has an extra column for the Post Kyoto scenario, which excludes the output from micro cogeneration. The message from this column is that owing to the electricity generating statistics described above, the EU target can only be achieved with the creation of the micro

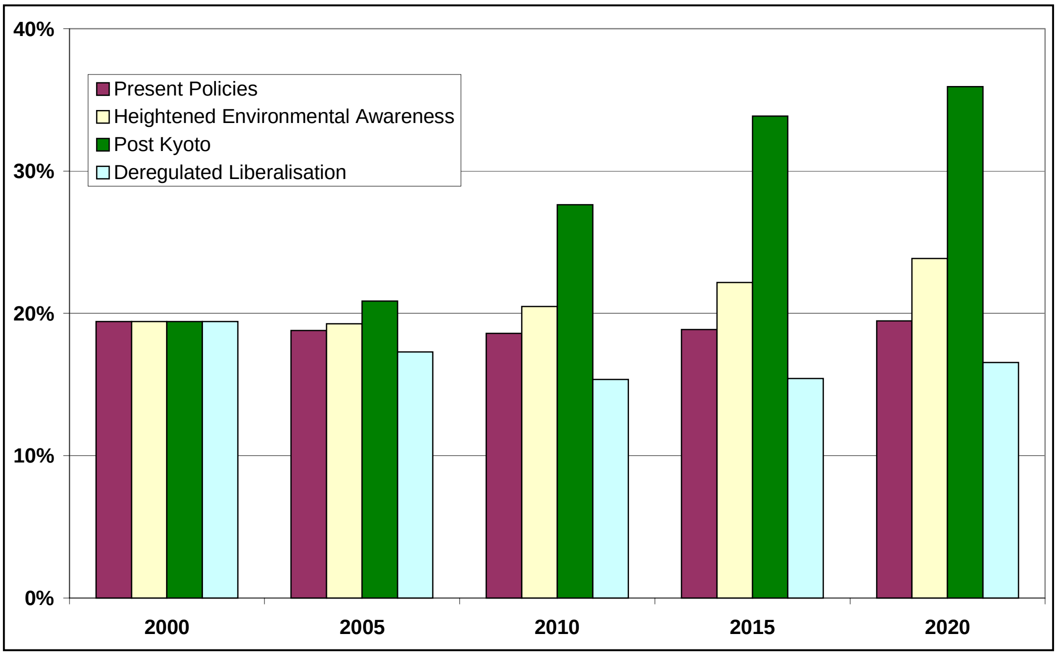
[13] Document COM (97) 514 final

[14] European Energy Outlook to 2020, Shared Analysis project, Special Issue November 1999, DG TREN, European Commission

cogeneration market. Without micro cogeneration, in the Post Kyoto scenario, cogeneration would only generate 17% of total electricity generation. Additionally, in the same scenario, there is a peak of non-domestic cogeneration at approximately 18% of total generation. Therefore, without the creation of this domestic sector market, the long-term prognosis for cogeneration is to only just reach the EU target.

The CEE countries currently do not have any regional cogeneration targets. However, the different scenarios have a significant effect on importance of cogeneration in terms of electricity generation. In figure 4.4, a similar effect occurs to that for the EU. In the Present Policies and Deregulated Liberalisation scenarios, the proportion of total generation falls, while it rises in the other two. However, it is only for Post Kyoto that significant increases in the relative importance of cogeneration as a source of electricity supply occur. In this case, the importance of cogeneration doubles from 19% to 36% of total electricity generation.

Figure 4.4 - CEE cogeneration electricity output as a proportion of total electricity generation



4.3 NEW MARKETS

Within the timeframe of the analysis, the only totally new market open to cogeneration is domestic sector micro cogeneration. This only opens in the Post Kyoto scenario, when the correct market and economic factors combine to stimulate the market. The potential for this market is over 50 GW_e of capacity by the year 2020, which will penetrate predominantly on the countries of Germany, United Kingdom, Italy, Netherlands and France. These countries predominate because of their large domestic energy markets, balanced heat and electricity demands in the domestic sector (thereby creating markets for micro cogeneration, unlike Spain), significant gas markets and networks, and high penetrations of consumers already using gas heating. These countries will hold almost 90% of the total EU market.

Figure 4.5 shows the penetrations of the main markets for micro cogeneration in the Post Kyoto scenario, while table 4.5 provides the data for all countries.

Figure 4.5 - Micro-cogeneration penetration (GW_e)

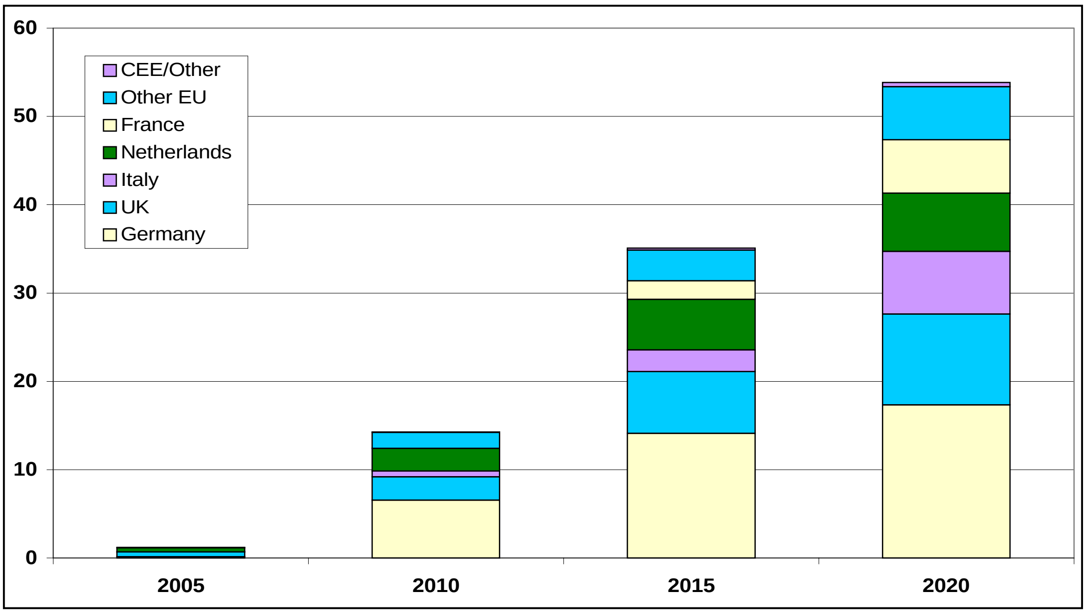
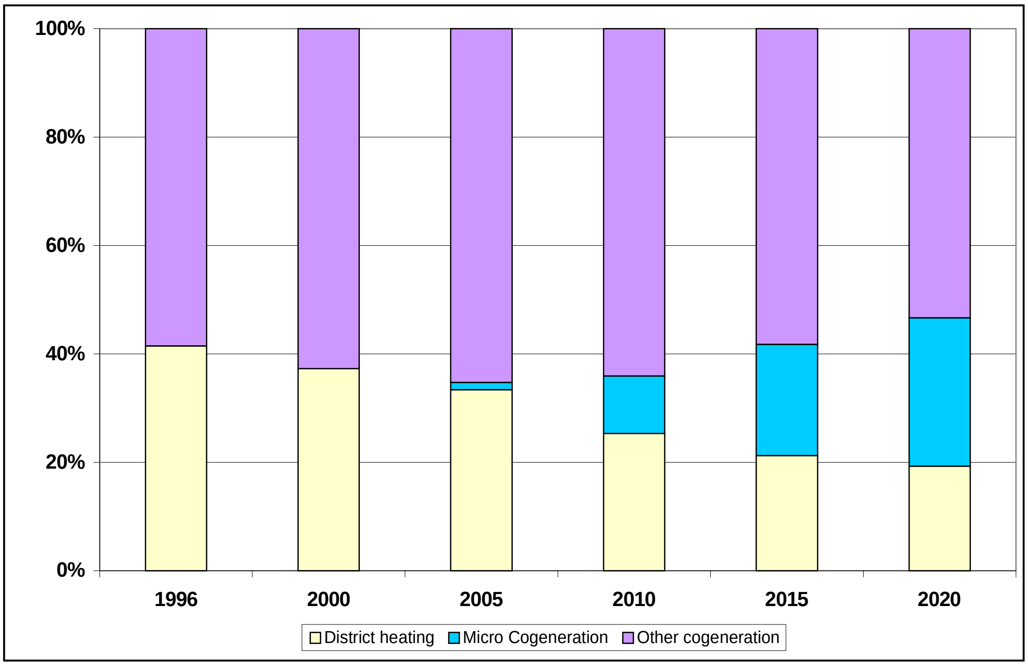


Table 4.5 - Micro Cogeneration capacity - Post Kyoto scenario (MW_e)

	2000	2005	2010	2015	2020
Austria	1	11	967	1086	1144
Belgium	0	0	56	610	2022
Denmark	0	1	557	1086	1269
Finland	0	8	111	119	126
France	0	0	0	2113	6056
Germany	0	140	7576	14139	17351
Greece	0	0	0	0	0
Ireland	0	8	40	95	108
Italy	0	19	639	2472	7105
Luxembourg	0	1	2	6	12
Netherlands	0	471	2552	5718	6574
Portugal	0	2	67	127	214
Spain	0	0	0	0	0
Sweden	0	1	17	347	1106
UK	0	547	2640	6964	10286
Bulgaria	0	1	9	19	24
Czech	0	0	3	13	25
Estonia	0	0	1	2	4
Hungary	0	0	3	14	28
Latvia	0	0	3	12	21
Lithuania	0	0	1	2	7
Poland	0	1	15	36	51
Romania	0	0	1	12	27
Slovakia	0	0	1	6	26
Slovenia	0	0	5	18	22
Cyprus	0	1	2	2	2
Norway	0	0	1	5	10
Switzerland	0	0	5	85	215
EU15 (GWe)	**0**	**1**	**14**	**35**	**53**
CEE (GWe)	**0**	**0**	**0**	**0**	**0**
Other (GWe)	**0**	**0**	**0**	**0**	**0**

The importance of micro cogeneration in the EU is shown in figure 4.6. By 2020, micro cogeneration will hold over a quarter of total cogeneration capacity in the EU. As it is currently zero, this shows a remarkable change in a twenty year period, which shows the importance of micro cogeneration as an electricity supply source of the future.

Figure 4.6 - EU micro-cogeneration penetration by share of capacity



At the same time, the importance of district heating as a source of electricity supply will diminish in the EU. Even in the Post Kyoto scenario, district heating in the EU is only expected to increase by 30% by 2020. The majority of this capacity will be the implementation of higher electricity ratio gas plant, which replaces older coal or oil fired plant, thereby maintaining a level thermal output from district heating cogeneration.

Micro cogeneration model validation

In addition to the SAFIRE modelling process, a calculation was also performed by the Sigma micro cogeneration model. The objectives of the exercise were twofold. These were to:

- test the new SAFIRE micro cogeneration methodology
- validate the outputs of the two models

Table 4.6 shows the outputs from both models for the EU15, with the SAFIRE results representing the Post Kyoto (best case) scenario.

Table 4.6 - EU 15 SAFIRE and micro cogeneration model 2020 predictions (MW_e)

Member State	SAFIRE	Sigma model
Austria	1144	2201
Belgium	2022	2201
Denmark	1269	1157
Finland	126	282
France	6056	6603
Germany	17351	20318
Greece	0	0
Ireland	108	141
Italy	7105	10159
Luxembourg	12	0
Netherlands	6574	6180
Portugal	214	0
Spain	0	0
Sweden	1106	1016
United Kingdom	10286	16085
EU total	**53373**	**66345**

Table 4.6 shows that there is a similarity in the results of the two models, thereby indicating, under the right conditions, that there is a significant potential for micro cogeneration in the EU 15. SAFIRE produces lower results (53 GW_e against 66 GW_e), but this is sufficiently similar to meet the objectives of the validation process.

4.4 FUELLING AND SUPPLY

As the penetration growth for cogeneration is potentially large, the fuelling of this new capacity is very important. Tables 4.7 to 4.14 show the cogeneration capacities, by fuel and by each scenario, for the EU and CEE.

In all scenarios and for all countries, the dynamics of the cogeneration market changes, with the replacement of coal and heavy fuel oil capacity with natural gas and to a lesser extent, biomass. However, the shape of the market directly affects the scope of this change and the actual capacity increases occurring for gas and biomass.

Table 4.7 - Cogeneration capacity by fuel- Present Policies scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	35774	40562	42093	45609	54949	63979
Coal & Products	16812	17778	17314	16706	14327	8906
Heavy fuel oil	7024	7482	7552	7168	6886	6425
Light oil & Diesel	2584	3218	3711	3945	4312	4888
Solid Biomass	2270	2362	2544	3180	4169	6759
Solid Wastes	2560	2617	2825	3115	3292	3619
Biogas	273	309	526	686	878	1166
Total (GW_e)	**67**	**74**	**77**	**80**	**89**	**96**

Table 4.8 - EU capacity by fuel - Heightened Environmental Awareness scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	35774	40562	44584	52855	64813	81871
Coal & Products	16812	17778	17337	16335	12743	7393
Heavy fuel oil	7024	7482	7866	7592	7422	6971
Light oil & Diesel	2584	3218	3725	4145	7427	10057
Solid Biomass	2270	2362	2736	4773	6857	12294
Solid Wastes	2560	2617	3061	3817	4400	5088
Biogas	273	309	934	1290	1695	1950
Total (GW_e)	**67**	**74**	**80**	**91**	**105**	**126**

Table 4.9 - EU capacity by fuel - Post Kyoto scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	35774	40562	48883	77006	107139	135378
Coal & Products	16812	17778	17030	15498	12918	7290
Heavy fuel oil	7024	7482	8445	8969	7188	5442
Light oil & Diesel	2584	3218	4620	11604	13944	15457
Solid Biomass	2270	2362	4021	11325	17655	19594
Solid Wastes	2560	2617	3550	5760	6638	7058
Biogas	273	309	1145	2069	2405	2479
Total (GW_e)	**67**	**74**	**88**	**132**	**168**	**193**

Table 4.10 - EU capacity by fuel - Deregulated Liberalisation scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	35774	40562	39872	39728	44785	55529
Coal & Products	16812	17778	15035	14696	13191	9344
Heavy fuel oil	7024	7482	7191	5745	5299	4765
Light oil & Diesel	2584	3218	3232	3346	3479	3885
Solid Biomass	2270	2362	2398	2473	2972	3937
Solid Wastes	2560	2617	2645	2734	2838	3009
Biogas	273	309	334	368	445	732
Total (GW_e)	**67**	**74**	**71**	**69**	**73**	**81**

Figure 4.7 shows the cogeneration capacity by fuel for the Post Kyoto scenario. Within the tripling of total capacity within the period of the study, gas cogeneration almost quadruples from 35 GW_e capacity to 135 GW_e, which is equal to over 70% of total capacity. The other fuels with high levels of growth are biomass (2 GW_e to 20 GW_e) and light oil and diesel (3 GW_e to 15 GW_e). Both coal and heavy oil capacity decreases over the period, as clean efficient fuels and technologies replace the old, inefficient and dirty capacity.

Figure 4.7 - EU Post Kyoto cogeneration capacity by fuel (MW_e)

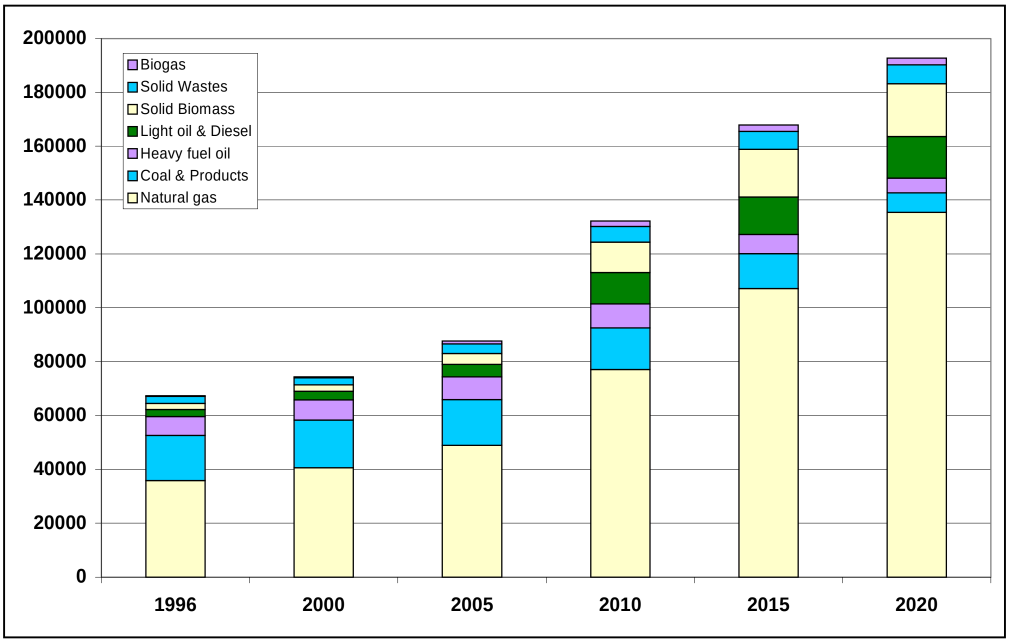


Table 4.11 - CEE capacity by fuel - Present Policies scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	7222	7222	7411	8078	10061	12389
Coal & Products	11639	11639	11649	11764	11418	10358
Heavy fuel oil	3889	3889	3905	3915	3834	3547
Light oil & Diesel	652	664	687	719	865	942
Solid Biomass	26	26	64	179	232	574
Solid Wastes	605	626	659	698	750	777
Biogas	195	196	204	223	265	368
Total (GW_e)	**24**	**24**	**25**	**26**	**27**	**29**

Table 4.12 - CEE capacity by fuel - Heightened Environmental Awareness scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	7222	7222	7987	11146	15744	20939
Coal & Products	11639	11639	11613	11538	10766	9015
Heavy fuel oil	3889	3889	3883	3839	3232	2341
Light oil & Diesel	652	664	703	804	974	1149
Solid Biomass	26	26	94	254	509	984
Solid Wastes	605	626	669	755	815	869
Biogas	195	196	217	283	378	451
Total (GW_e)	**24**	**24**	**25**	**29**	**32**	**36**

Table 4.13 - CEE capacity by fuel- Post Kyoto scenario (MW_e)

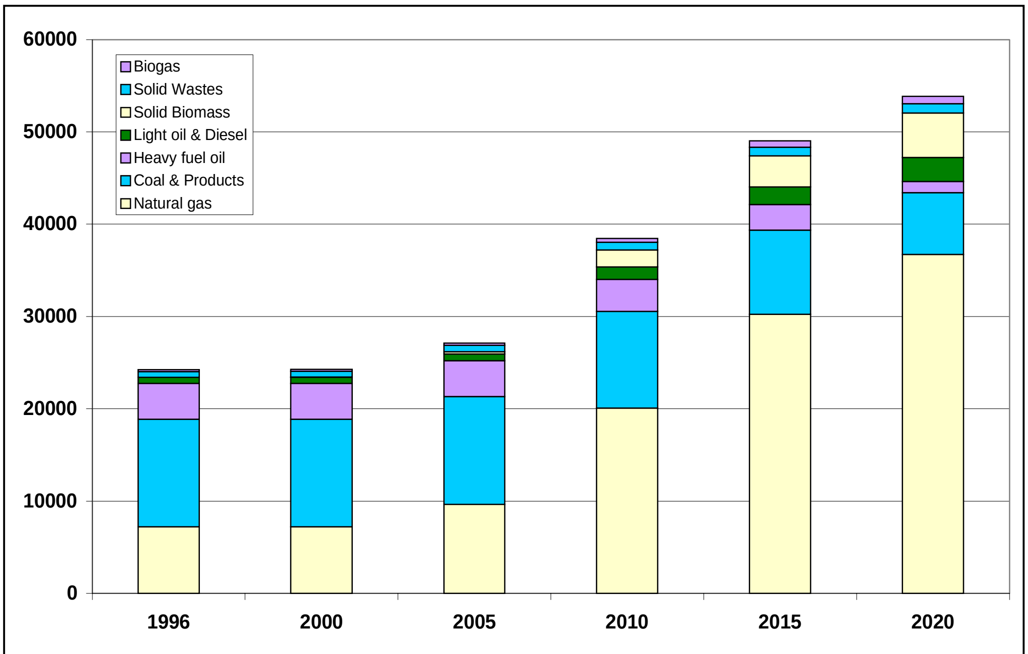
EU total	Base	2000	2005	2010	2015	2020
Natural gas	7222	7222	9659	20073	30235	36710
Coal & Products	11639	11639	11664	10469	9107	6689
Heavy fuel oil	3889	3889	3871	3488	2777	1225
Light oil & Diesel	652	664	752	1339	1927	2595
Solid Biomass	26	26	235	1852	3355	4837
Solid Wastes	605	626	687	826	952	976
Biogas	195	196	234	401	678	813
Total (GW_e)	**24**	**24**	**27**	**38**	**49**	**54**

Table 4.14 - CEE capacity by fuel- Deregulated Liberalisation scenario (MW_e)

EU total	Base	2000	2005	2010	2015	2020
Natural gas	7222	7222	6874	6356	7776	10892
Coal & Products	11639	11639	11010	10474	10187	9383
Heavy fuel oil	3889	3889	3514	3201	2798	2358
Light oil & Diesel	652	664	652	636	681	813
Solid Biomass	26	26	41	62	124	289
Solid Wastes	605	626	630	620	638	713
Biogas	195	196	202	215	237	283
Total (GW_e)	**24**	**24**	**23**	**22**	**22**	**25**

Figure 4.8, which shows cogeneration capacity in the CEE, shows a similar situation to figure 4.7. The major growth area is for gas fired cogeneration, as it is assumed that the political inertia against the use of gas supplies from Russia has been overcome. Significant growth is also shown by biomass. Coal and heavy fuel oil each decrease by over 50%, as old stock is replaced.

Figure 4.8 - CEE Post Kyoto cogeneration capacity by fuel (MW_e)



4.5 THE DIVIDEND

Emissions reductions are a key supporting factor of cogeneration. This section presents the methodology in the emissions calculation and the conclusions from ***future* cogen**.

4.5.1 Methodology

A number of key assumptions have been used in the emissions reduction calculations for cogeneration. These include the following:

- The majority of cogeneration plant replaces centralised electricity and boilers
- The majority of substituted centralised electricity plant is fossil fuel fired. It is assumed that cogeneration plant does not substitute base load output, such as large hydro and nuclear electricity
- Substitution occurs according to the fossil mix and not the most likely replaced technology. Therefore, the savings are likely to be initially underestimated as less efficient plan will be substituted first
- The emissions saved should be calculated at the point of use and not at the electricity source
- The majority of retrofit activity and old cogeneration plant replacement will occur in Central and Eastern Europe

Table 4.15 shows the numbers used in the emissions reductions calculation. The assumptions above and numbers in this table were used to calculate the results specified in section 4.5.2.

Table 4.15 - Emissions reduction values

Category	Value	Units
Carbon content of fuel		
- Coal	328	kg/MWh (GCV)
- Gas	180	kg/MWh (GCV)
- Mix oil	255	kg/MWh (GCV)
- Fossil mix EU (57% coal, 43% gas)	264	kg/MWh (GCV)
- Fossil mix CEE (70% coal, 25% oil, 43% gas)		
Network losses		
- EU	7	%
- CEE	14	%
Central generation		
- [15]Fossil mix EU CO_2 emissions at end user	695	g/kWh
- Fossil mix CEE CO_2 emissions at end user	1481	g/kWh
Boilers		
- Efficiency	80	%
- Emissions from coal fired	410	g/kWh
- Emissions from gas fired	225	g/kWh
- Emissions from oil fired	333	g/kWh
- Share of boilers EU (coal/oil/gas)	0.2/0.6/0.2	-
- Share of boilers CEE (coal/oil/gas)	0.6/0.3/0.1	-

From these assumptions and emission factors, the net emissions savings occurring from cogeneration are calculated as:

CO_2 saving = *emissions from cogeneration plant - ([electricity + heat] emissions substituted)*

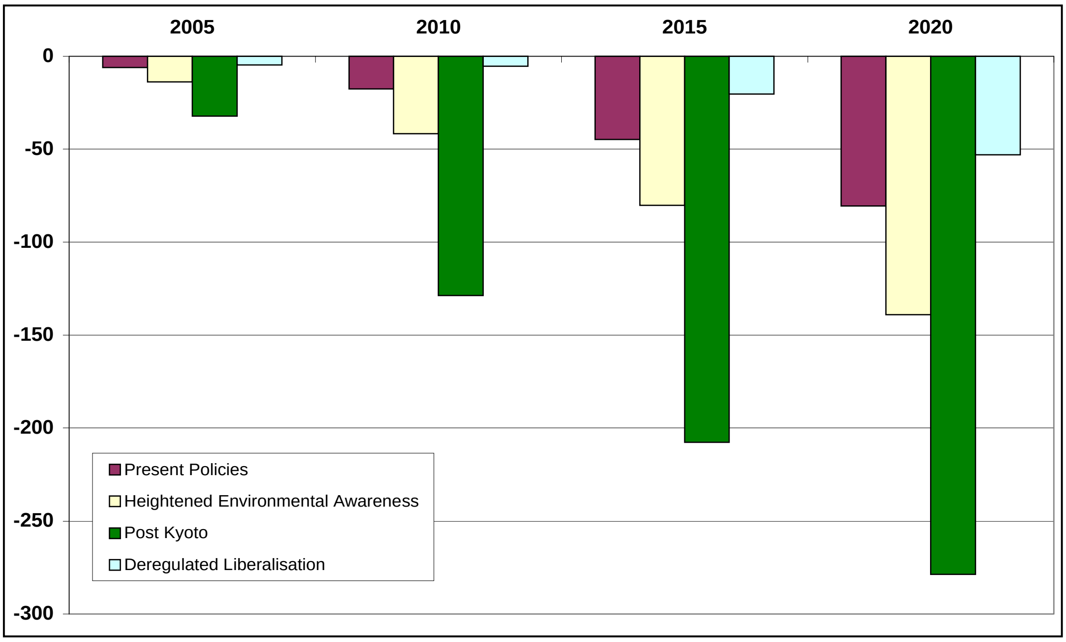
[15] The Fossil Mix emissions values takes electricity network losses into account

4.5.2 Emissions Reductions

As specified in the Post Kyoto scenario, the main benefit of cogeneration is its efficient use of energy. The mechanisms of the Kyoto Protocol will support cogeneration economically, and as cogeneration is an economic and efficient technology that is robust and proven, the potential for significant emissions reductions is high

Figure 4.9 shows the EU CO_2 emission savings for each of the four scenarios in comparison to cogeneration not penetrating. For these figures, a 2000 base year has been used. In the Post Kyoto scenario, the total annual emissions savings are almost 150 million tonnes of CO_2 by 2010 and 300 million tonnes by 2020. This compares with the next best scenario which only achieves half these savings, and a Present Policies saving of less than a third. For the worst case Deregulated Liberalisation scenario, no major emissions savings are achieved until after 2010, which would have a major effect on the national greenhouse gas emission reduction targets held by the member states of the EU.

Figure 4.9 - EU cogeneration emission savings from 2000 (Mt CO_2)



In terms of the EU's Kyoto emission reduction targets, cogeneration has a major part to play towards achieving the targets. However, the target cannot be met from cogeneration alone, even in the Post Kyoto scenario. Table 4.16 shows the effect of EU cogeneration on the total EU CO_2 emissions figures. It shows that despite the significant savings achieved by cogeneration, this is more than offset by increased emissions occurring from economic growth, with total EU CO_2 emissions greater in 2010 than they were in 1990, which shows a major failure in climate change policy. Therefore, cogeneration must be viewed as one of a range of emissions mitigation measures, in conjunction with energy efficiency and renewable energy. However, in terms of supply side technologies, cogeneration is the best option in the short to medium term as cogeneration is a mature technology, economic and it can provide rapid benefits towards achieving the targets.

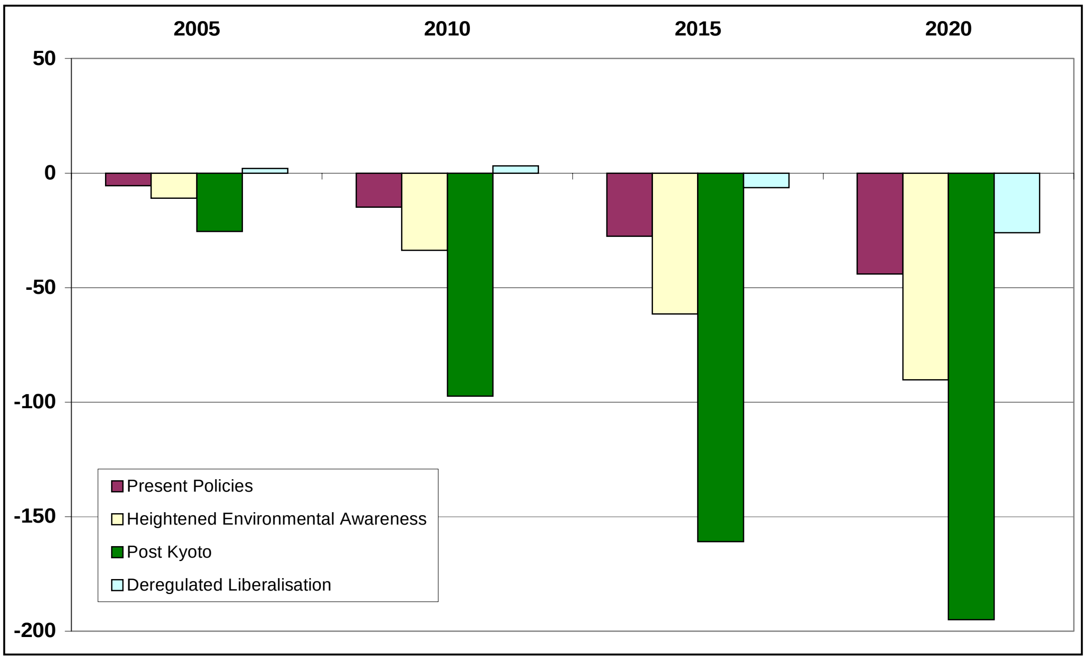
Table 4.16 - EU cogeneration CO_2 emissions savings from 2000, Post Kyoto scenario (Mt/year)

	1990	2005	2010	2015	2020
Total emissions[16]	3079	3245	3298	3402	3508
Kyoto target	-	-	2833	-	-
Savings (from 2000)	-	32	127	200	268

Note: The Kyoto target is for an 8% reduction in greenhouse gases in 2010 from 1990. The 2833 Mt is an indication of the emissions target if the same 8% is applied to CO_2

For Central and Eastern Europe, the emissions savings show a similar relationship between scenarios, except at a lower level (figure 4.10). There is a potential to reduce annual emissions in the region by almost 200 million tonnes of CO_2. Emissions in the CEE are proportionately higher per unit of cogeneration capacity than in the EU. This is owing to the lower generation efficiencies in the region, the higher dependence upon coal as a fuel and from the higher levels of transmission and distribution losses. The emissions figures do not take into account the likelihood that system losses will be reduced in the next 20 years, which will slightly reduce the total emission reductions attributable to cogeneration.

Figure 4.10 - CEE cogeneration emission savings from 2000 (Mt CO_2)



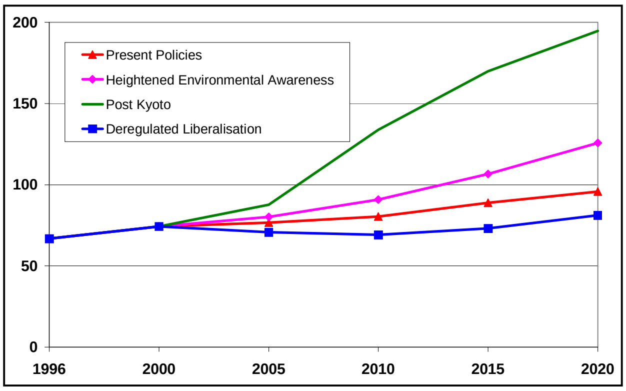
[16] European Union Energy Outlook to 2020, Shared Analysis Project, November 1999

5 COUNTRY REVIEW

The graphs in this section reflect the total cogeneration capacity for each scenario in each country studies in ***future* cogen**. All of the graphs refer to **cogeneration capacity** and are in units of MW_e, except for the regional ones, which display GW_e. Brief summary notes from the individual country reports have been included for each country and region covered by ***future* cogen**.

5.1 EUROPEAN UNION

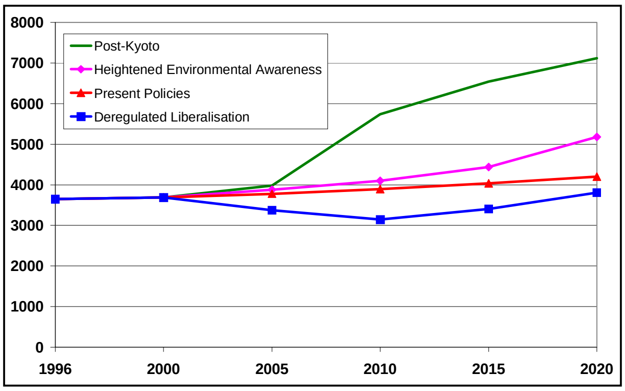
Cogeneration currently supplies about 10% of generated electricity. The majority of this plant is in the industrial sector. Fuelling is increasingly dominated by gas, which has been replacing coal during the last decade. During the next 20 years, cogeneration capacity in the European Union is predicted to almost triple from approximately 70 GW_e to 190 GW_e. This majority of this growth will be shared between the industrial (to 2010) and domestic micro cogeneration (after 2010) markets.



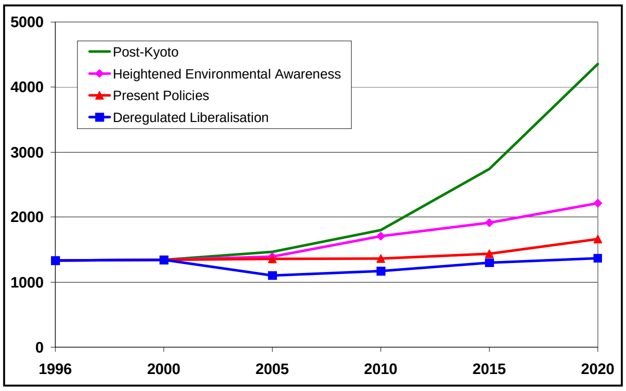
The EU has set a target to double cogeneration production as a proportion of generation between the base year and 2010 (from 9% to 18%). This target (graph not shown) is only achieved in the Post Kyoto scenario, primarily owing to the pessimism currently active in the cogeneration industry. Liberalisation is occurring at different speeds in each Member State. There are currently no specific polices aimed at cogeneration, but ***future* cogen** supports the development of a Cogeneration Directive.

Austria

Cogeneration is currently well established in Austria, which limits the scope for future development. It supplies 77% of thermal electricity (66% of total production is large hydro). Per capita CO_2 emissions are low, so reductions are relatively difficult. Liberalisation has been slow, causing uncertainty. In the best case scenario, growth is expected in the district heating, domestic and industrial sectors.

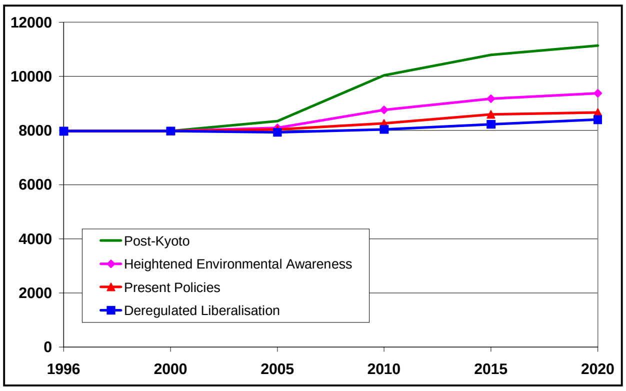


Belgium



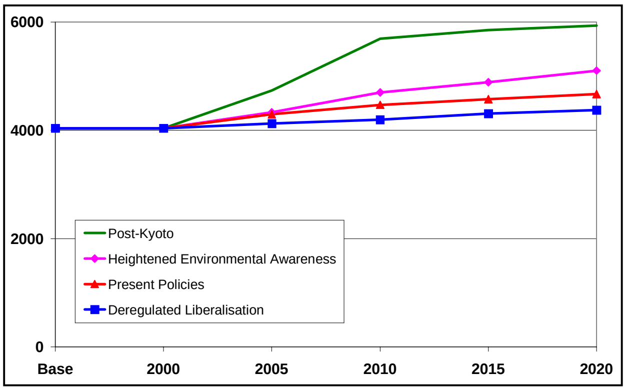
Current installed capacity is mainly industrial sector, with some large scale commercial applications. The majority of the industrial plant is located in Flanders, which is where industry is located. Fuelling is primarily from gas or by multi-fuelling. Government support is viewed as not being particularly co-ordinated. The quality of cogeneration is an important factor; cogeneration should lead to an overall reduction in primary energy consumption.

Denmark



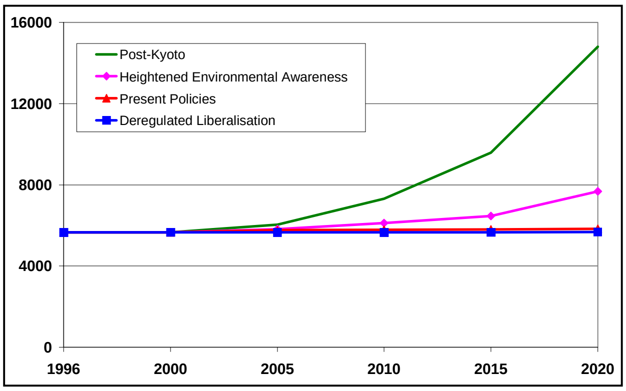
Cogeneration provides about 50% of electricity production, mainly in the district heating sector. Gas is the primary fuel, followed by waste and biomass. Cogeneration and district heating have a good public image. Most cogeneration potential has already been developed. The main growth potential is in the domestic sector and for larger scale industrial plant. Denmark has expressed a desire to be a market leader in the international cogeneration market.

Finland



Cogeneration supplies about 32% and 75% of electricity and heat respectively, mainly in the district heating and industrial sectors. Fuelling is from gas, coal, industrial wood residues and peat. The electricity market is fully liberalised, gas not at all. There is a fuel tax used for heat production, but not for electricity. As penetration is already high, growth potential is low, most of which occurs from upgrading of district heating plant to lower electricity:heat ratios.

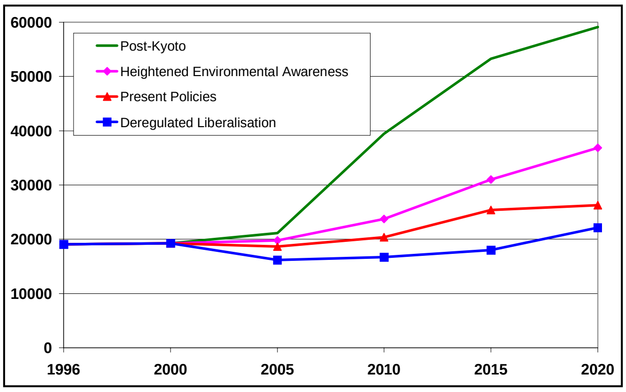
France



Cogeneration supplies 2% of generation and is mainly used in large scale industrial applications. Gas and heavy fuel oil are the main fuels. There is an over capacity of electricity generation. Liberalisation is lagging the rest of the EU. There are no specific targets or support mechanisms for cogeneration. No growth is expected without significant market changes. Micro cogeneration has a major potential by 2020.

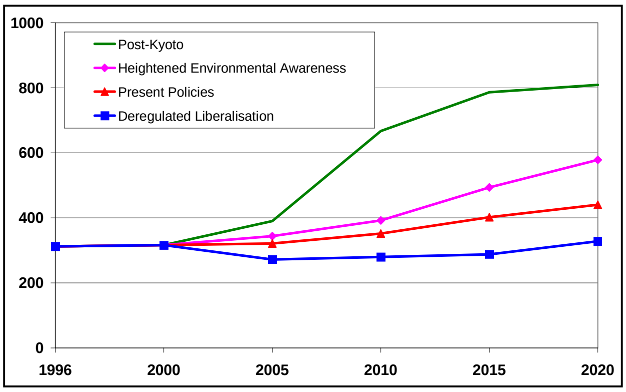
Germany

Cogeneration contributes 10% of electrical capacity, divided between the industrial and district heating sectors. Fuelling is mainly from gas and coal. Electricity liberalisation has caused price falls, leading to plant closures. The political attitude is favourable, but long-lasting negotiations on support measures have delayed any concrete action. The growth potential is shared mainly between the industrial and domestic micro cogeneration sectors.



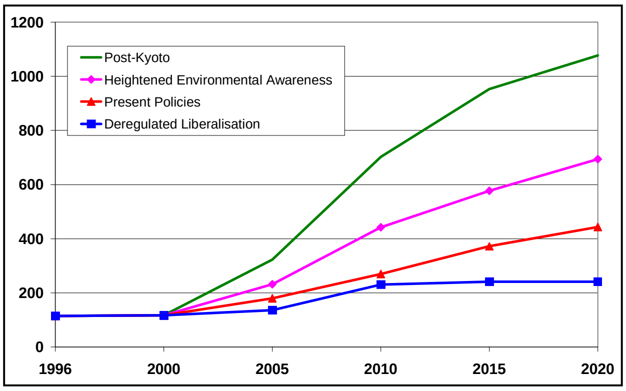
Greece

Cogeneration supplies 2.5% of electricity. The district heating/cooling market is small; the former is expected to develop in the north. The majority of larger industrial applications have already been installed. A gas network is currently being developed. Market barriers are being removed. Growth is expected to more than double capacity, mainly for medium scale industry and large scale commercial applications.



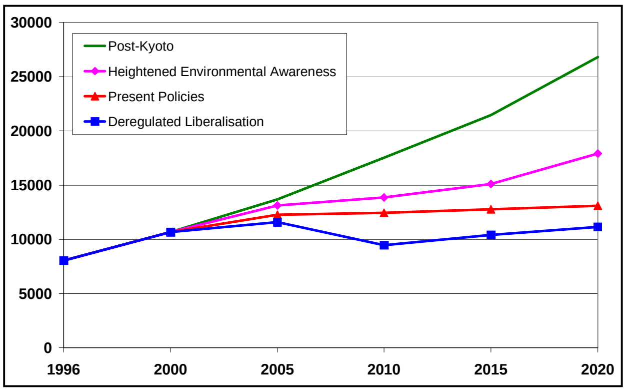
Ireland

Cogeneration supplies 2.1% of electricity, mainly in the industrial sector. There is no district heating. Electricity price falls and gas price rises have decreased the viability of cogeneration. In October 2000, the government set out concrete CO_2 emission targets attributable to cogeneration. Electricity market regulations currently are a market barrier, but it is still expected to grow through a doubling of demand by 2020. Growth is expected in the large scale industrial and commercial sectors.

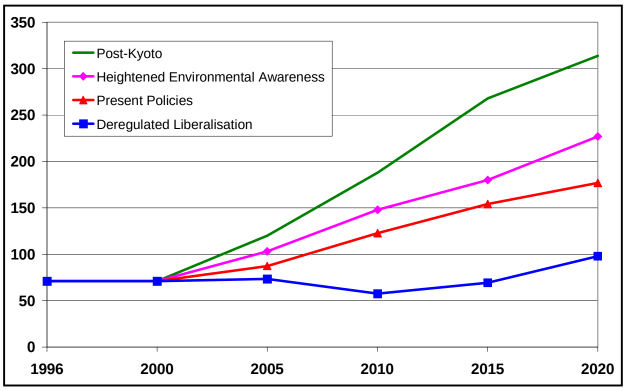


Italy

Cogeneration supplies about 16% of electricity. It is dominated by large scale industrial plant. Liberalisation is having an effect on the cogeneration potential. Current growth is based upon three large industrial plants. There currently is little other construction. Cogeneration schemes are currently uneconomic against grid supplied electricity. No support measures are currently used or planned. Growth will be in the domestic and industrial sectors.

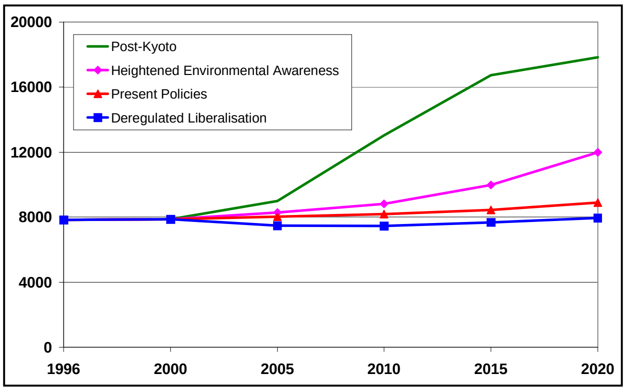


Luxembourg



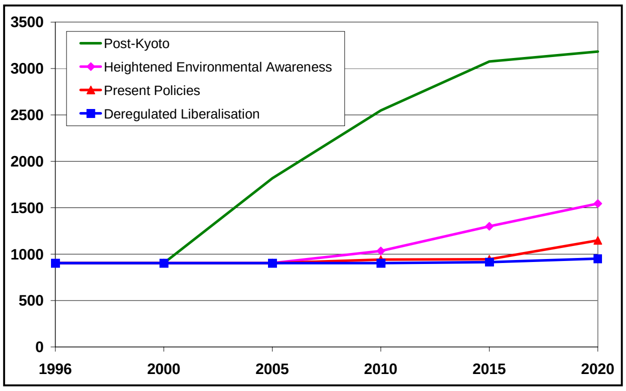
Cogeneration amounts to 58% of electricity production, but 95% of electricity is imported. Output is predominantly in the industrial sector and is mainly fuelled by gas. Security of supply pays a major part in policy. Support is positive, with focused policies both current and planned. Luxembourg has one of the most positive regimes for cogeneration at this time. Growth is expected in all sectors, particularly in industry.

Netherlands



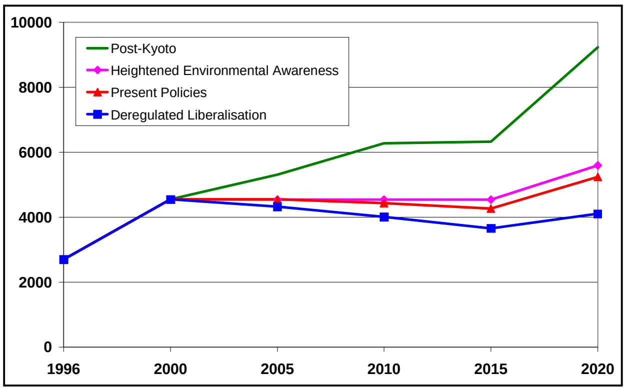
Cogeneration installation levels are high, at 38% of total generation capacity. This is predominantly gas fired, which is widely available. An unofficial target has been set to double current capacity to 15 GW_e by 2010. Liberalisation is causing problems as electricity prices fall and gas prices rise. All support has been stopped with the exception of sophisticated cogeneration schemes. The main opportunity is in the domestic micro cogeneration market, with a potential of 6.5 GW_e by 2020.

Portugal



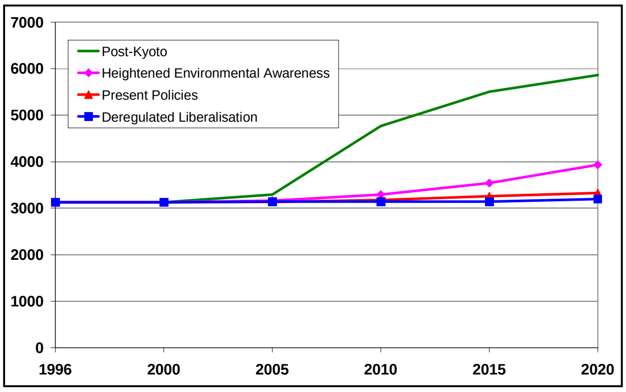
Cogeneration supplies 16% of electricity demand, almost all in the industrial sector. About 90% of Portugal's energy requirements are imported. The gas network, introduced in 1997, is expanding. Decreasing electricity prices are stifling the market. Cogeneration plant is supported financially by the government. The growth markets continue to be the industrial sector, followed by the commercial and domestic sectors.

Spain



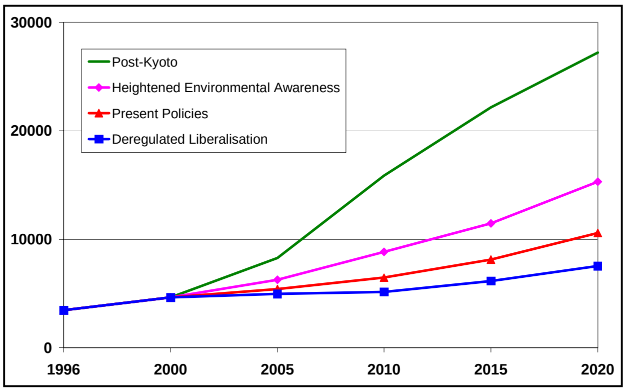
Cogeneration expanded rapidly in the 1990s, especially in the industrial sector, owing to a positive market framework. This positive situation has now stopped primarily due to falling electricity prices. Current support policies prevent optimum sizing of plant above 10 MW_e, while plant above 50 MW_e are ineligible. Further growth in cogeneration is only expected in the best case scenario.

Sweden



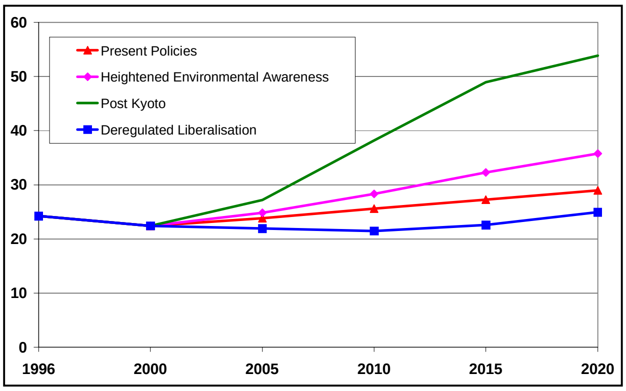
Cogeneration accounts for 6% of electricity production, divided evenly between industry and district heating. Cogeneration in Sweden is not well developed, despite a strong district heating sector. Competition from hydro and nuclear power remains high, but the potential phase out of nuclear plant will boost the prospects for cogeneration. Growth markets are in the domestic and large scale industrial sectors, with some scope for district heating.

United Kingdom



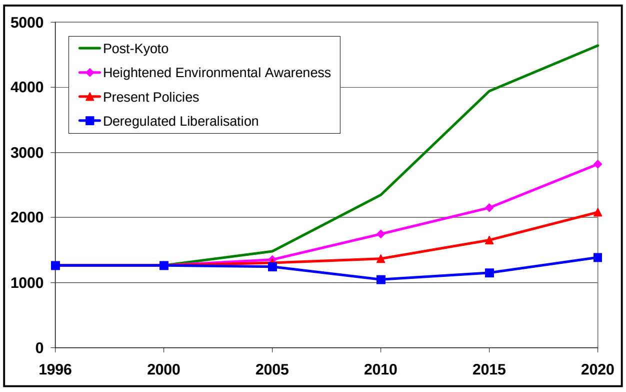
Cogeneration accounts for 5% of total installed capacity, mostly in the industrial sector. Gas price rises and electricity price falls have eroded cogeneration economics, which has been exacerbated by the new trading arrangements. There is no real government strategy towards cogeneration, but targets will be set in the forthcoming strategy. Under the Post Kyoto scenario, more than a third of all capacity could be micro cogeneration.

5.2 CENTRAL & EASTERN EUROPE



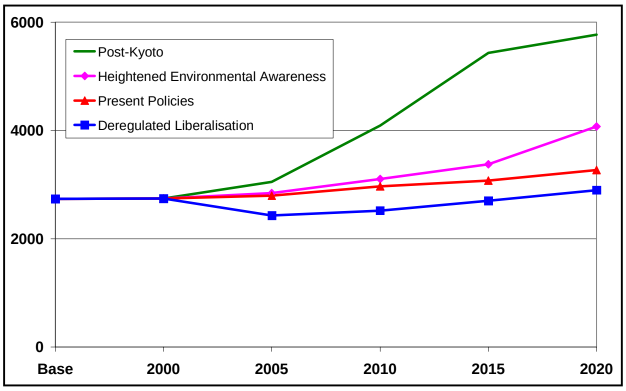
Cogeneration supplies a significant proportion of electricity in Central and Eastern Europe. A large proportion of the plant is old, especially in district heating, and it is predominantly coal fired (about 50%), with most of the remainder fuelled by gas or heavy fuel oil. Energy sector liberalisation is generally just starting in the region, so there is the potential for national governments to learn from the experiences of the EU. The key driver in support of cogeneration is generally the desire to achieve accession to the EU. There is also significant potential from making use of the Join Implementation mechanism of the Kyoto Protocol. National greenhouse gas emissions reductions generally are not an issue, as the economies of the majority of the CEE countries have contracted significantly since 1990, thereby automatically achieving their emissions targets. Compared with the EU, the potential for micro cogeneration is relatively small (1 GW_e by 2020). The potential for cogeneration in the CEE countries is to increase capacity by around 250% in the next twenty years with the majority of the growth fuelled by natural gas. Biomass capacity also increases to approximately 5 GW_e.

Bulgaria



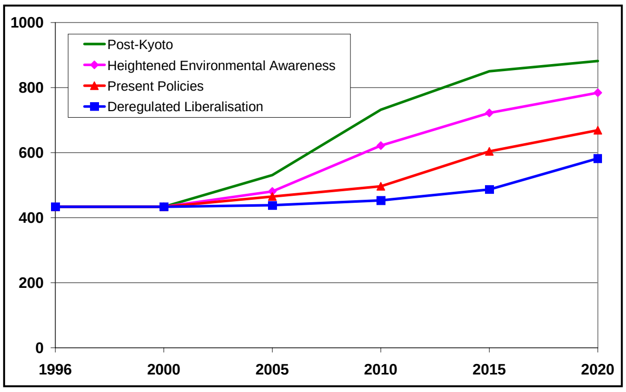
Cogeneration comprises 16% of total electrical capacity, located in the industrial and district heating sectors. The installed stock is old, and there now is electrical over capacity. No new capacity has recently been constructed, partly owing to lack of funds and finance. Government policy to 2010 has provisions for cogeneration. The main growth potential is in the industrial and district heating sectors, with a mix of refurbished and new capacity.

Czech Republic



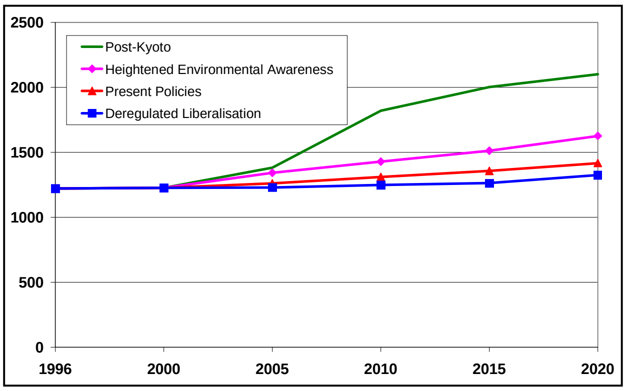
Cogeneration supplies 18% of electrical demand, mainly for industry and district heating. Fuelling is mainly coal, with some gas and waste firing. Gas prices are three times higher than coal. Liberalisation does oblige suppliers to purchase cogeneration electricity, but it does not protect against price competition. Cogeneration is supported in principle, but there are no specific plans or policies. Growth is mainly in the medium-scale industrial sector.

Estonia



There are only 15 facilities, primarily fuelled by oil shale. Capacity is primarily in the district heating and large scale industrial sectors. Most plant need modernisation. Liberalisation is expected to be completed in 2005. Gas supplies, from Russia, are currently politically undesirable. There are no current or planned policies specific to cogeneration. Growth is expected in the district heating industrial sectors, partially through refurbishment.

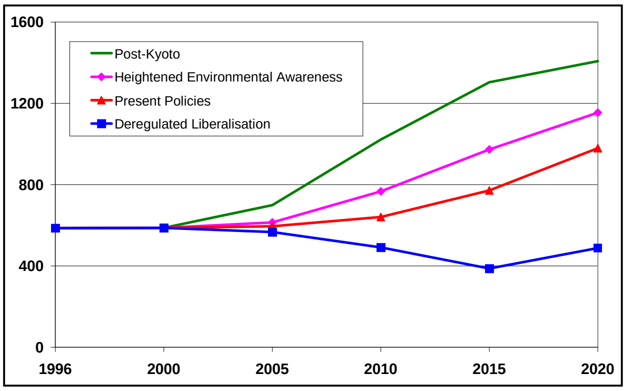
Hungary



Cogeneration supplies about 10% of electricity, mainly fuelled by coal but with an increasing role from gas. A lot of district heating capacity is old. The gas network is widespread. There is a compulsory power purchase agreement for plants under 20 MW_e. Liberalisation is not yet achieved. There is little government support for cogeneration, but it is listed as a priority in energy policy. Growth is expected in the industry and district heating sectors.

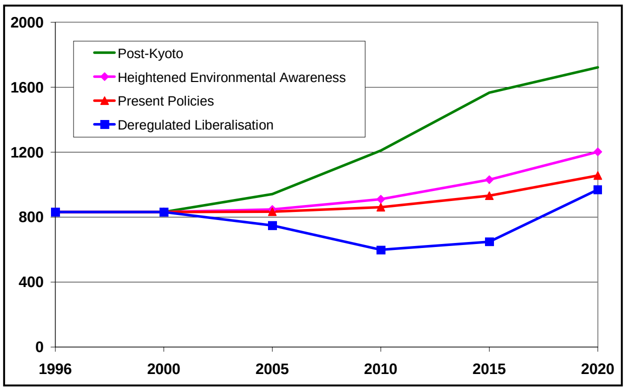
Latvia

Most applications are for district heating, which suffers from over capacity. The installed stock is old, and recent investment has concentrated on efficiency improvements. Electricity prices are low due to hydro capacity and cheap imports. District heating plant investment is possible, but being delayed by the financial viability of some of the companies. New capacity developments will be dominated by refurbishment.



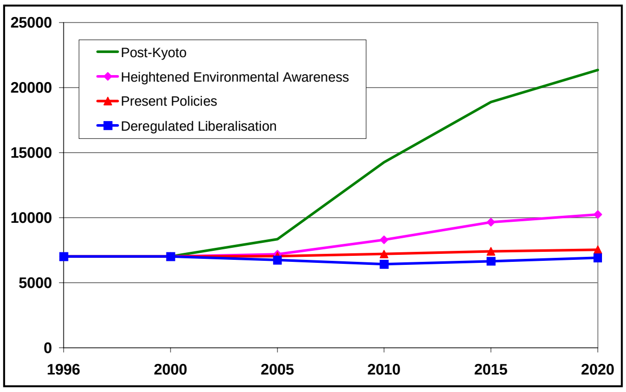
Lithuania

Cogeneration represents 11% of capacity, with most of it (90%) in the district heating sector. Current plant is old and requires refurbishment. Fuelling is mainly heavy fuel oil and gas. The Ignalina nuclear plant dominates capacity. Lithuania is a net exporter. Electricity prices are low owing to over capacity and low nuclear prices. There are no specific targets for cogeneration. Growth is mainly from refurbishment in the district heating sector.



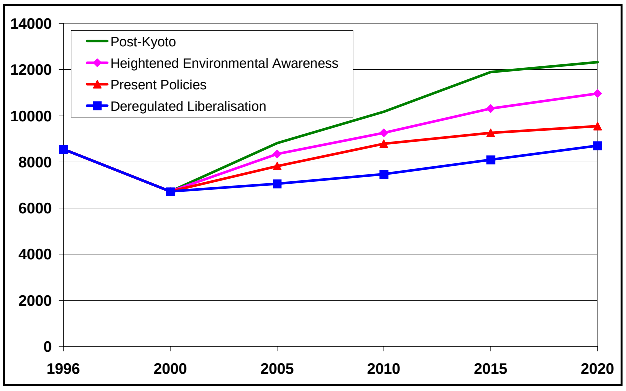
Poland

There is a long history of cogeneration, with capacity in the industrial and district heating sectors. About half of district heating output is supplied by cogeneration plant. The majority of plant is coal fired, with moves towards gas already starting. Electricity liberalisation is well progressed, but gas has not started. Gas pipelines are under construction from Russia (to Western Europe) and Norway. Total efficiencies greater than 65% are promoted. Capacity could triple in the best case scenario.



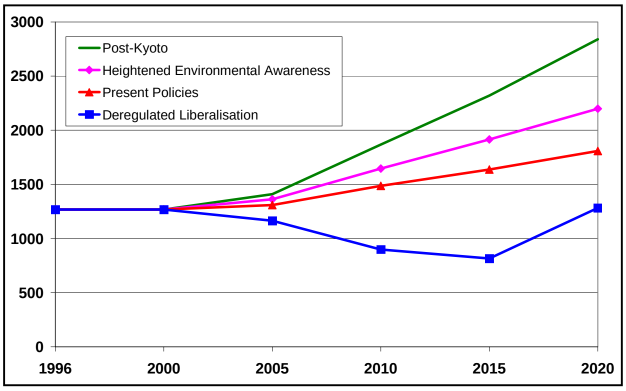
Romania

About 40% of electricity is generated by cogeneration plant, almost all in the district heating sector. Existing plant is generally old. Gas resources are good and the network is being expanded. There are no specific policies. Energy price subsidies continue to penalise cogeneration. A short term strategy could lead to the replacement of cogeneration with boilers. The growth markets are district heating refurbishment and the industrial sector.



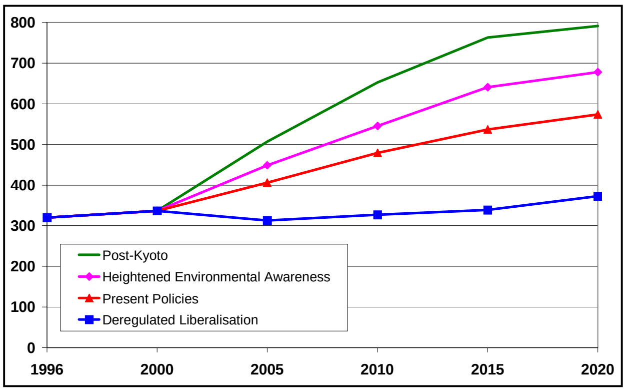
Slovak Republic

Cogeneration is mainly located in the district heating and industrial sectors. Government support is limited to indirect measures, but general national and international mechanisms do exist to support cogeneration. Market growth areas are predominantly in the commercial and district heating sectors. The main issue for policy makers is the need to speed up energy market reforms and to restructure the electricity supply side.



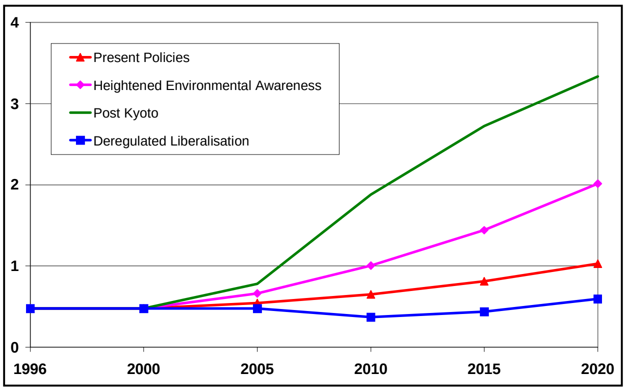
Slovenia

Cogeneration supplies about 8% of power production. Industry and district heating networks providing the bulk of installed capacity. Most plant is old, leaving significant opportunities for refurbishment. The commercial and domestic sector potential is estimated to be small. The natural gas network is expanding rapidly. Support measures are currently aimed at plant refurbishment or replacement, as opposed to developing new capacity.



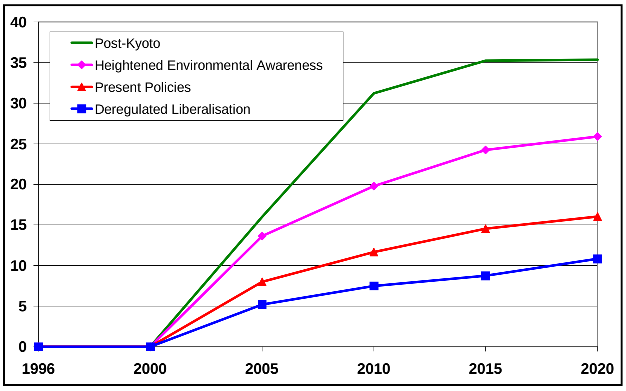
5.3 OTHER COUNTRIES

The three remaining countries of Cyprus, Norway and Switzerland are all almost unique within the ***future* cogen** project. Cyprus and Norway have almost no current capacity between them and have little potential for growth. Switzerland has the most federalised system in Europe, which leads to both advantages and disadvantages for cogeneration. Therefore, the majority of the growth prospects are in Switzerland.



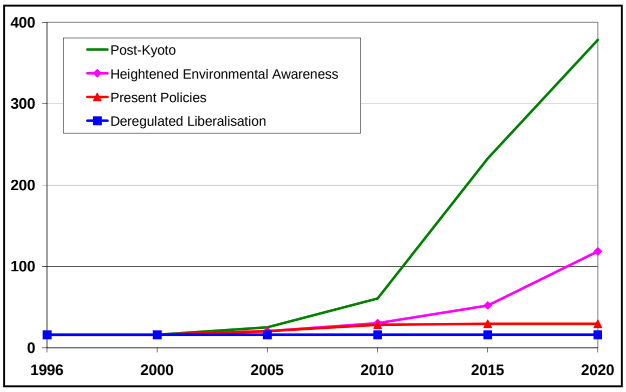
Cyprus

There currently is no installed cogeneration capacity. Liberalisation is planned after 2003, but privatisation of the Electricity Authority will not happen. Cogeneration is relatively "unknown". There is neither current nor planned support for cogeneration. Space heating requirements are minimal and domestic water heating requirements are met by solar heating.



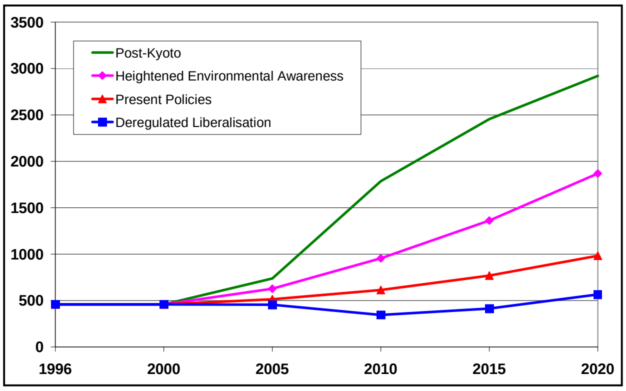
The main market is for small industrial applications that require process heat.

Norway



Cogeneration is almost non-existent owing to the dominance of hydropower. With the exception of the oil and gas sectors, industry is small. District heating has a small role to play. There are no specific policies promoting cogeneration and there is no national target. Electricity prices are low and gas use is low. Some growth is possible, but it is likely to be small.

Switzerland



Cogeneration currently supplies 50% of thermal electricity and 2.5% of total production, owing to significant hydro and nuclear capacity. There are no specific targets directly supporting cogeneration, but it is expected to contribute towards a 10% CO_2 emissions reduction target. An energy tax will be implemented in 2004 if necessary to achieve the CO_2 targets. The main areas of growth are in the district heating and medium scale industrial markets.

6 CONCLUSIONS & RECOMMENDATIONS

The conclusions from the ***future cogen*** team are of major importance to the cogeneration industry. These conclusions have been endorsed by both the modelling process and the consultation workshops, but also reinforced by other experience and knowledge during the course of the project.

6.1 CONCLUSIONS

There is a **single primary conclusion** that is currently affecting the whole industry, which is the assessment of **risk**. In pure economic terms and under current policy frameworks, cogeneration is becoming a marginal technology in Europe, whose future potential is under threat. By minimising the medium to long term risk for the cogeneration industry, cogeneration will become the technology of choice and will achieve significant penetration, which will lead to many added benefits in terms of emissions reductions, industry expansion, quality of life, etc.

There are a number of conclusions that arise from ***future* cogen**, that are both positive and negative. At the current time, the negative factors are dominating the cogeneration market, which is causing major concern in the industry and is directly affecting for cogeneration in the short term and potentially causing significant damage to the confidence of the whole industry. However, they can easily be overcome by implementing a few simple, but important, factors.

6.1.1 Positive

Unless specified in the individual conclusions, all of the conclusions refer to the results from the best case Post Kyoto scenario. Additionally, owing to the variable base year in the country analysis, the comparison between marker years uses a starting point of the year 2000, unless specified otherwise.

General/Markets

- the potential for cogeneration is to almost **double total cogeneration capacity** in the EU (74 GW_e to 135 GW_e) between 2000 and 2010, and to almost triple capacity by 2020 (to 195 GW_e)
- cogeneration has the **potential to supply 22% of generated electricity** in the EU by 2020. However, this is based upon the assumptions of energy generation under the Conventional Wisdom scenario[17], which if reduced, could lead to a higher proportion than this
- cogeneration capacity in Central and Eastern Europe has the **potential to increase by 50%** by 2010 (22 GW_e to 38 GW_e) and to double by 2020 (to 54 GW_e)
- cogeneration has **the potential to save 127 million tonnes of CO_2** emissions in the EU by 2010, which is equal to 4% of total CO_2 emissions. In 2020, **268 million tonnes** of savings are possible (8% of total emissions)

Policy/Regulatory

- the aim of **doubling electricity generation from cogeneration by 2010** is possible, but only in a best case scenario

[17] European Energy Outlook to 2020, Shared Analysis project, Special Issue November 1999, DG TREN, European Commission

- based upon the results from the modelling process, **the future of cogeneration lies in Climate Change and the Kyoto** flexible mechanisms associated with Climate Change. The Post Kyoto scenario is the only scenario with full Kyoto ratification, which enables the full internalisation of the external costs in the energy market
- **liberalisation can support cogeneration**, but only if the liberalisation process is regulated (e.g. Luxembourg)
- the **European Commission has an important role to play** through the implementation of policies supporting the long-term development of cogeneration particularly in light of cogeneration's considerable positive contribution to European Kyoto Climate Change targets and to improving security of energy supply
- for the Central and Eastern European states, **accession to the European Union** is directly affecting energy policy in these countries

Technology

- technological change has the opportunity to open **major new markets** for cogeneration
- **micro-cogeneration** can achieve major benefits for cogeneration and the environment, providing up to 30% of all new capacity in the next twenty years
- **gas is the future fuel in the CEE** countries, with the potential to double its share of cogeneration fuelling by 2020
- up to **11 GW_e of biomass cogeneration** could be installed by 2010 in the EU, with an additional 8 GW_e by 2020

6.1.2 Negative

General/Markets

- **investment risk** is a major threat to cogeneration in Europe
- **uncertainty** is currently dominating the cogeneration industry, caused by both market signals and the lack of a legislative and regulatory framework (e.g. the new NETA arrangements in the United Kingdom)
- in the worst case scenario, lack of investment in cogeneration would lead to **increases in CO_2 emissions**
- **insufficient information** is being given to the cogeneration industry on future policies, etc. The net effect of this lack of information is a state of limbo that leads to pessimism and negative results
- even under the best case scenario, **EU non-domestic cogeneration production is unlikely to surpass 18% of total electricity generation**. Any additional growth requires the creation of new cogeneration markets such as micro cogeneration
- cogeneration economics is **very sensitive to gas prices**, for which the outlook is uncertain owing to the different stages of gas liberalisation in Europe

Policy/Regulatory

- unless significant changes are made to policy and infrastructure, the aim of **doubling the proportion of EU electricity from cogeneration by 2010 will not be achieved**
- **liberalisation can damage cogeneration** if it is implemented in a deregulated manner, leading to wide scale plant closure (e.g. Germany)

- The Commission's **Green Paper on Security of Energy Supply**[18] **has little mention of cogeneration**, despite it being an important energy saving technology

Technology

- the largest long term market growth potential is for **micro cogeneration**, but it will not happen without changes in energy markets and infrastructure

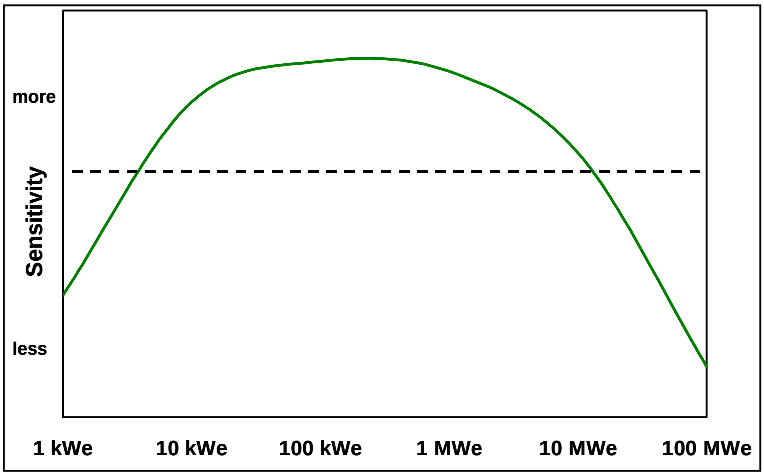
Taking these factors into account, the key message from ***future*** **cogen** is that cogeneration has the potential to play a major part in Europe's energy mix of the future, but that there many factors that are likely to impede this progress. For example, electricity sector liberalisation in many European countries, with such a large over-capacity in Europe, has driven down the price of electricity to levels that make even cogeneration uneconomic without internalising cogeneration's environmental benefits. Coupled with the fall in electricity prices is the effect that gas liberalisation is having on gas markets and prices, which has recently been greatly exacerbated by the link between gas and oil prices. It has become increasingly clear to the ***future*** **cogen** team that the adaptation of the energy market through simple market instruments towards cogeneration will help Europe to achieve its emissions reductions' targets.

6.1.3 Market Sensitivity

A key result from the project is that the scenarios, and the policy and market conditions that make up these scenarios, have wide ranging effects on the growth of the cogeneration market. This, of course, is to be expected, as cogeneration requires favourable legislative and electricity and gas market conditions if it is to prosper, and investors require appropriate returns on their investment with acceptable risk.

However, one aspect of the results that has arisen from the project is the link between the size of cogeneration plant and its sensitivity to market conditions. The modelling demonstrates that under the two better case scenarios (Heightened Environmental Awareness and Post Kyoto), cogeneration achieves its highest relative penetration in the large industrial and domestic sectors. This implies that, once any market barriers have been removed, both sectors are less sensitive to market conditions. A visual representation of the impact of market conditions on cogeneration growth is given in figure 6.1.

Figure 6.1 - Cogeneration risk graph



In figure 6.1, the likelihood of cogeneration investment can be represented in terms of a horizontal (dashed) line, which represents the status of perceived risk towards the development of cogeneration plant. Based upon this assumption, all plant below the line is more likely to be economic in the long term and will lead to higher relative penetrations of these sizes. Therefore, for the future cogen project, the differences between the scenarios is the equivalent of moving the horizontal line up and down, with Post Kyoto having the highest line and Deregulated Liberalisation the lowest.

[18] Green Paper: Towards a European strategy for the security of energy supply, COM (2000) 769

From the shape of the graph, it can be seen that cogeneration systems below 10 kW_e and above 50 MW_e are less sensitive, while those in the sizes in between are much more sensitive to market conditions.

During the meetings attended by the core project team, this phenomenon was discussed. Based upon graph itself and the experience of the team members, the following conclusions were reached:

- Provided that the installation of micro-cogeneration is allowed, then it is less affected by electricity and gas prices and by the other factors. The large uncertainty for this technology is focused on the ability to connect to the electricity networks at reasonable prices
- The route to market for micro-cogeneration is most likely through utility companies and their exposure to market risk is different than non-utility companies, especially if they also have gas and electricity trading divisions
- Large cogeneration plant is developed under all scenarios, the vast majority of these schemes are developed by utility players and thus they have a different risk profile to schemes developed by independent Energy Service Companies (ESCOs) and by the cogeneration host sites themselves
- Cogeneration plants in the sizes between micro-cogeneration and over 50 MW_e are generally not developed by utility companies. These schemes, therefore, represent a competitive threat to the central electricity business. This may well mean that it is much harder for individual projects to be developed and thus much more prone to the market conditions and the regulatory regime in each country

6.2 RECOMMENDATIONS

A number of clear recommendations arise from ***future cogen***. These apply to both international and national government and policy makers, towards supporting a market that includes the real costs of energy generation. The **primary recommendation** is to **minimise the risk** associated with investment in cogeneration. This can be achieved in a number of ways, each of which will send the correct signals to the cogeneration market.

General/Markets

- support the development of cogeneration by **establishing a cogeneration certificates market**. By having certificates of origin, this is another means of internalising the low externalities of cogeneration and creating a new market that will increase the expansion of new cogeneration development
- The production of a **standardised definition of cogeneration** is necessary to support the widespread development of the technology. This will help to condense the current dispersed 'national' industry into a European wide one that can become a world leading industry. It is proposed that a definition should refer to "good quality" cogeneration, similar to the definition used by Eurostat. It should recognise that electricity is more valuable than heat and show the benefits of cogeneration relative to the individual equivalents. The definition may vary for different plant sizes, technologies applications and load factors

Policy/Regulatory

- **ratify the Kyoto Protocol** and implement the three flexible mechanisms as soon as possible. This will encourage clean and efficient technologies, of which cogeneration is a prime mover

- policy makers and governments need to **send a clear and consistent message to the cogeneration industry** on intentions and developments on both regulations and intentions. This will instil confidence in the industry and lead to new development. None of the other recommendations will work effectively if this one is not fulfilled
- establish **legislation that is specifically aimed at cogeneration** (e.g. a cogeneration Directive), which might, for example, address planning issues and embed cogeneration as the technology of choice over electricity or heat generation, even at a small scale, and to place an obligation on suppliers to purchase a proportion of their supply from cogeneration
- give **energy market regulators the duty to encourage growth in cogeneration** (a practical measure that is easy to implement)
- **focus on small to medium cogeneration**, as this area currently involves the most risk
- **legislate against restrictive practices** discouraging the establishment of cogeneration units, such as prohibitive grid connection costs, lengthy procedures for generation licensing, etc.
- **cut the link between oil and gas prices**. Volatility in oil markets is causing major distress to the cogeneration industry, which is particularly relevant to the last six months
- **strengthen the link between cogeneration and security of supply**

Technology

- **open up new markets for cogeneration**, particularly in the domestic sector for micro cogeneration. This will increase the potential cogeneration market by around 30%
- **further analysis of the micro cogeneration markets** is advised, owing to the huge potential in this market
- shift the emphasis of electricity supply away from large centralised systems towards **smaller decentralised markets**
- **support micro cogeneration in two ways** - the regulation of connection agreements (both from a technical and commercial viewpoint), and the introduction of simplified metering, settlement and trading procedures

The potential for cogeneration in Europe is large, and the industry has the opportunity to become a major part of the region's energy needs of the future. However, there are significant threats facing the industry today. If these are not surmounted, the potential benefits from cogeneration, such as emissions reductions, will be lost in the short to medium term. The time to act is now, and the challenge needs to be met if this potential is to be realised.