Cogeneration in Europe (Spotlight on Belgium)

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As every country in Europe has a different approach towards cogeneration, a global overview is hard to give. The structure of the energy sector and a decent government policy used to be the key factors in the success of cogeneration leading to a very different status of cogeneration in each country. However, nowadays the ongoing liberalization of the gas and electricity sector has an overwhelming impact on cogeneration. Where it leads a level playing field and strong impulse for cogeneration in one country, it is also the reason why cogeneration has to struggle to survive in many other countries.

First an overview of cogeneration in Europe is presented with in section two a focus on Belgium. Section three tries to give the most important elements for the future. Apart from the ongoing restructuring of the energy sector, new technologies as mini (and micro) cogeneration deserve special attention. Finally section four summarizes the main conclusions.

1. COGENERATION IN EUROPE

Figure 1 gives an overview of cogeneration in Europe (as a share of national power production) indicating a range from a few percent (France, Belgium…) up to 40 percent and more for such countries as Denmark, Finland and the Netherlands. As figures are based on national statistics with each country using its own definition of cogeneration,[1] Figure 1 has to be interpreted carefully, however, main trends are clear.

Countries as Denmark and the Netherlands have known an active

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*In many countries a large share of cogeneration capacity consists of district heating systems, boosting statistics.

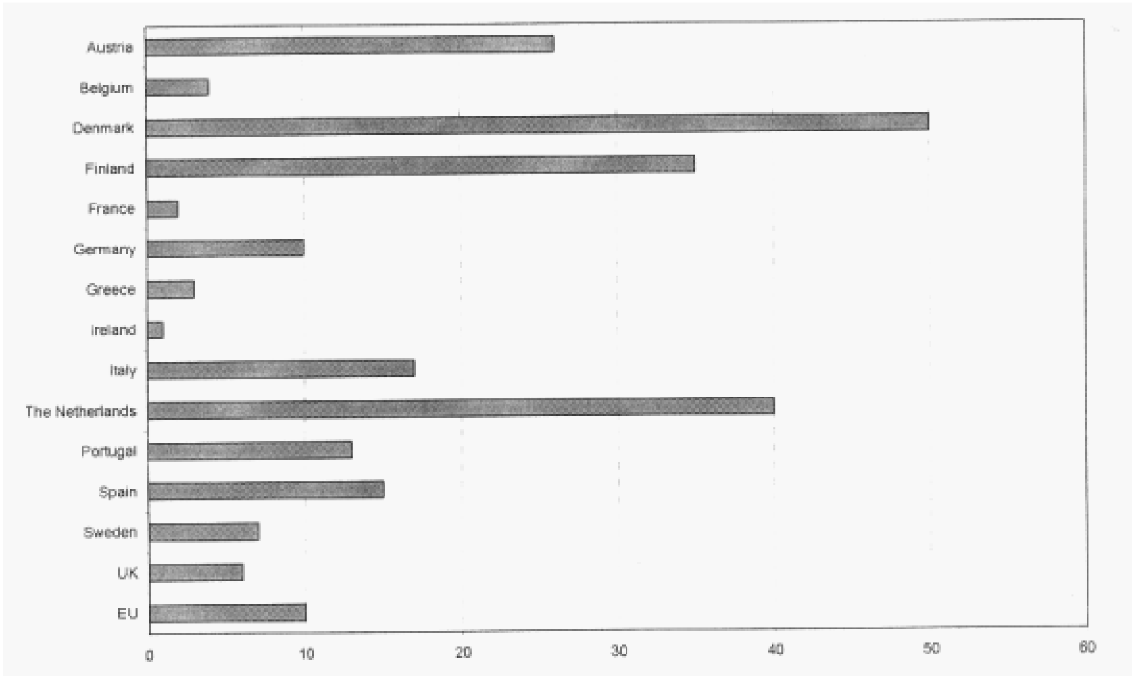


Figure 1. Cogeneration as a Share of National Power Production (1999) (Source: Cogen Europe)

policy on cogeneration resulting in a large share for cogeneration in national power production. In Finland, the third major cogenerator in Europe, the moving force used to be the absence of barriers mainly in the sense that the electricity market has always been organized in a fairly liberal way. In absolute numbers (Megawatts) Germany has the largest share of cogeneration in Europe (a large share is district heating), but the overall picture is rather complicated. The German energy sector is very much diversified (approximately 1,000 electricity companies) and being a federal state it has difficulties developing a coherent policy.

In the countries mentioned above, together with Austria and Italy, cogeneration is a well-established technology. There are however some European countries where realizing cogeneration projects is a difficult task. France is considered to be the ultimate challenge for cogeneration since the technique has never had many chances there, due to the centrally organized electricity sector, which is almost exclusively based on nuclear power generation. Although to a lesser extent, the same was true for Belgium. Finally there are some countries where cogeneration still remains an unknown concept (Ireland, Greece) mainly due to a poor infrastructure. Recent developments in Spain and Portugal however show that such countries too have a large potential.

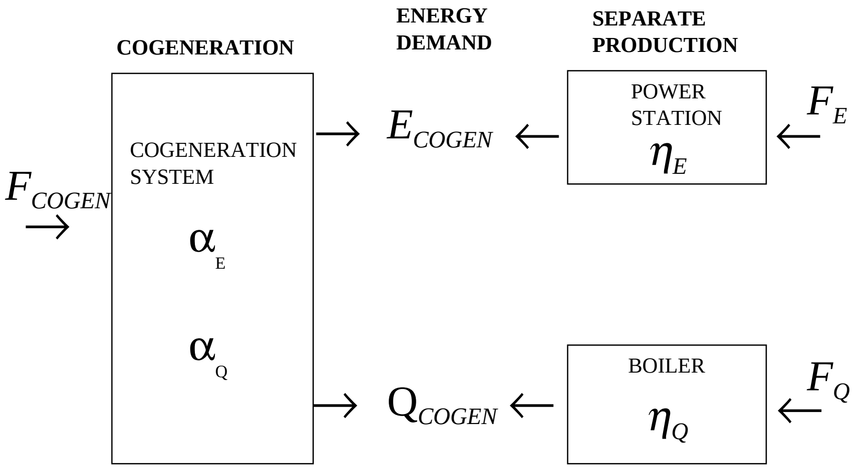
2. COGENERATION IN BELGIUM

Apart from industrial steam turbine applications, cogeneration has remained an unknown concept for a long time; the main reason for this being a highly monopolistic electricity sector and the lack of a decent energy policy. The Belgian energy scene is dominated by the Tractebel group, owning Electrabel as well as Distrigas. Apart from a smaller public company, Electrabel is the only electricity producer in Belgium and Distrigas the only gas company. At a policy level, Belgium took the nuclear choice leading to a centrally organized energy sector. Nowadays competencies are scattered among different authorities, mainly due to Belgium's progress from a central to a federal state.

Quality of cogeneration

In the early nineties, at Vito (Flemish Institute for Technological Research) the first steps were taken to promote cogeneration. Compared to other countries emphasis is not on quantity (Megawatts) but rather on quality (energy savings). Every cogeneration project is compared with "separate production," Figure 2 giving the well-known cogeneration scheme.

In this well-known scheme, efficiencies of "separate production" are rather high. A combined cycle with an efficiency of 55% is taken as a reference for electricity production, a boiler with an efficiency of 90% as a reference for thermal energy production. Figure 3 is the graphic translation of Figure 2, establishing the boundary conditions for cogeneration to realize any energy savings.



F_{COGEN}	:	fuel input cogeneration	[GJ]
α_E	:	electric efficiency cogeneration	[%]
α_Q	:	thermal efficiency cogeneration	[%]
E_{COGEN}	:	electricity demand	[GJ]
Q_{COGEN}	:	heat demand	[GJ]
F_E	:	fuel input power station	[GJ]
η_E	:	electric efficiency power station	[%]
F_Q	:	fuel input boiler	[GJ]
η_Q	:	thermal efficiency boiler	1%]

Figure 2. Basic Scheme Cogeneration

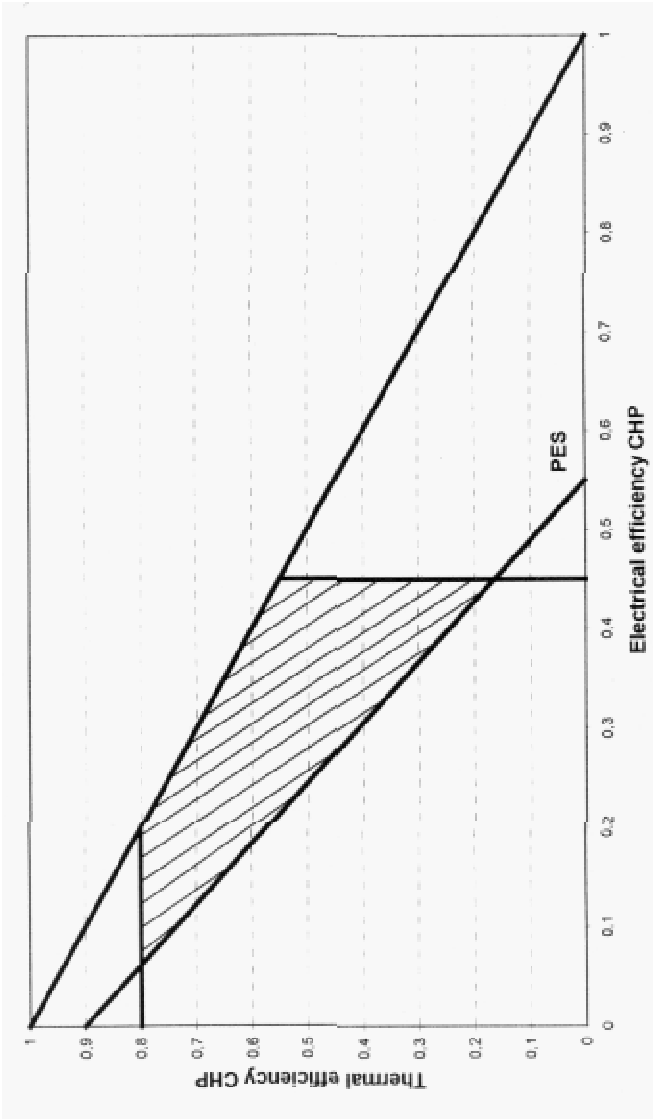


Figure 3. Boundary Conditions for Energy Saving by Cogeneration

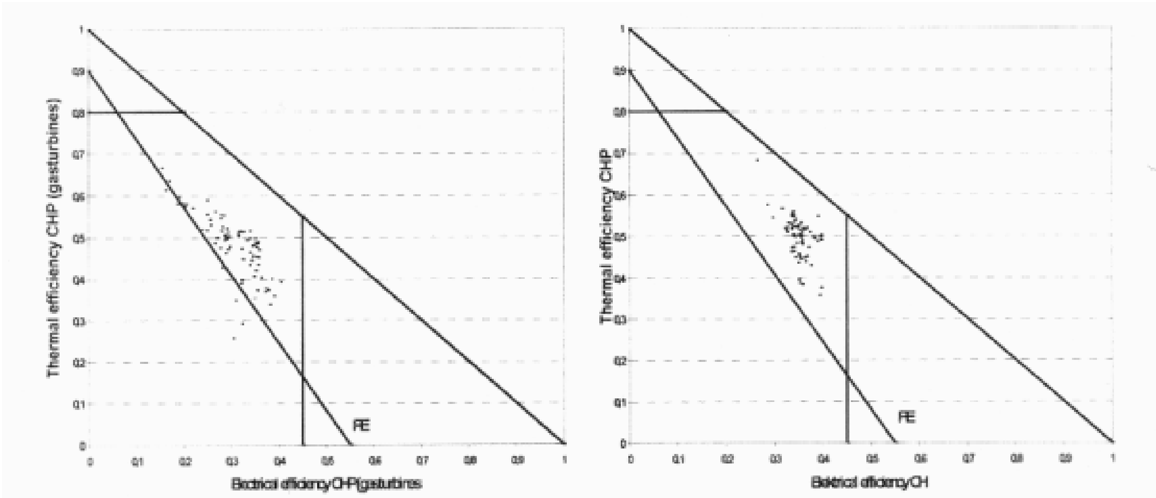


Figure 4. Efficiencies of Commercially Available Gas Turbines and Reciprocating Gas Engines in Relation to the PES-boundary Condition

- The PES-line (primary energy savings) constitutes the minimum requirement for each cogeneration project to realize any energy savings; intersections with the x-axis and y-axis are the efficiencies of separate thermal and electrical energy production;
- The horizontal and vertical line are the peak thermal and electrical efficiency of relevant cogeneration technologies (gas-turbines and reciprocating engines);
- The bisector is the perpetuum mobile line; a technology above this line deserves the Nobel Prize.

In order to get the quality label, every cogeneration project has to be within the shaded area. Fortunately, most relevant cogeneration technologies have an adequate performance, enabling them to meet the basic requirement. Figure 4 displays efficiencies of commercially available gas turbines and reciprocating engines on natural gas, showing that the boundary condition is well met most of the time.

This approach can be extended to other technologies for cogeneration as well as other references for electricity (and heat) production. In addition, not only energy savings but also CO_2-emission reduction can be analyzed. **The most important conclusion in this respect is that cogeneration remains a front-rank technology for a rational use of energy, even with the severest references taken into account.**

As far as CO_2-emission reduction is concerned the situation is more complicated as a straightforward comparison is often prevented by the use of different fuels. In Belgium, gasoline is still a relevant fuel for cogeneration (reciprocating engines) but hardly a choice for electricity production. Compared to a combined cycle on natural gas, a reciprocating engine on gasoline still realizes a significant saving in primary energy (in GJ energy) but has a negative impact on CO_2-emissions (in tons CO_2). Although relevant within the Kyoto protocol, this has little to do with cogeneration as a technology or concept.

Cogeneration in Belgium

Together with the more theoretical concepts of “quality of cogeneration,” Vito determined the cogeneration potential for Belgium. Based on the requirement for energy saving, the energy demand of various sectors and a well-proven dimensioning methodology, total cogeneration potential was estimated at about 3.000 MW_e (electricity production capacity amounts to 15.000 MW_e in Belgium). The most important cogeneration sector is the chemical industry with refineries and the food industry to follow (gas turbines). Apart from industry, horticulture, hospitals and large office buildings are relevant sectors for cogeneration with reciprocating engines. The bulk of the potential is situated in the Flemish Region, with Antwerp Harbour offering a large part of it.

The Vito work was the basis for cogeneration in Belgium. Although the energy sector was very reluctant towards decentralized production in the beginning, large-scale cogeneration systems have become a core business of Electrabel. In spite of the fact that Belgium is a small country, there is lot of industry, especially around the Antwerp Harbour. In this area, approximately 600 MW_e of cogeneration is realized on the basis of gas turbines, the LM 6,000 being Electrabel's favorite. In view of the ongoing market liberalization, customers' relations are the main reason to install large-scale cogeneration projects.

At the small-scale level (reciprocating engines) Electrabel's success is rather modest. It has never been a well-meant choice of Electrabel to promote small-scale cogeneration projects with fuel switching (from oil to gas) being the main reason to promote cogeneration at this level. Although there are some successful projects of independent power producers, the lack of know how is often a major obstacle (apart from unfair tariffs for backup power, excessive regulation towards grid connection and the absence of a government policy). At the end of 1999, the installed capacity of small-scale cogeneration was about 100 MW_e industry, horticulture and hospitals being the most popular sectors.

Figure 5 presents an overview of cogeneration in the Flemish Region in Belgium. The figure for 2004 is the government objective of an extra 600 MW, cogeneration capacity. As the potential for cogeneration with larger gas turbines is almost realized, small-scale projects will have to take a major part in these 600 MW_e.

3. FUTURE TRENDS FOR COGENERATION IN EUROPE

At the end of the eighties, the first documents on liberalization of the energy sector were laid down on a European level. Nowadays, as the legislative procedure comes to an end, most countries having adopted the European directives in their national laws. At the moment, liberalization is the key word in every energy-related subject. But the impact

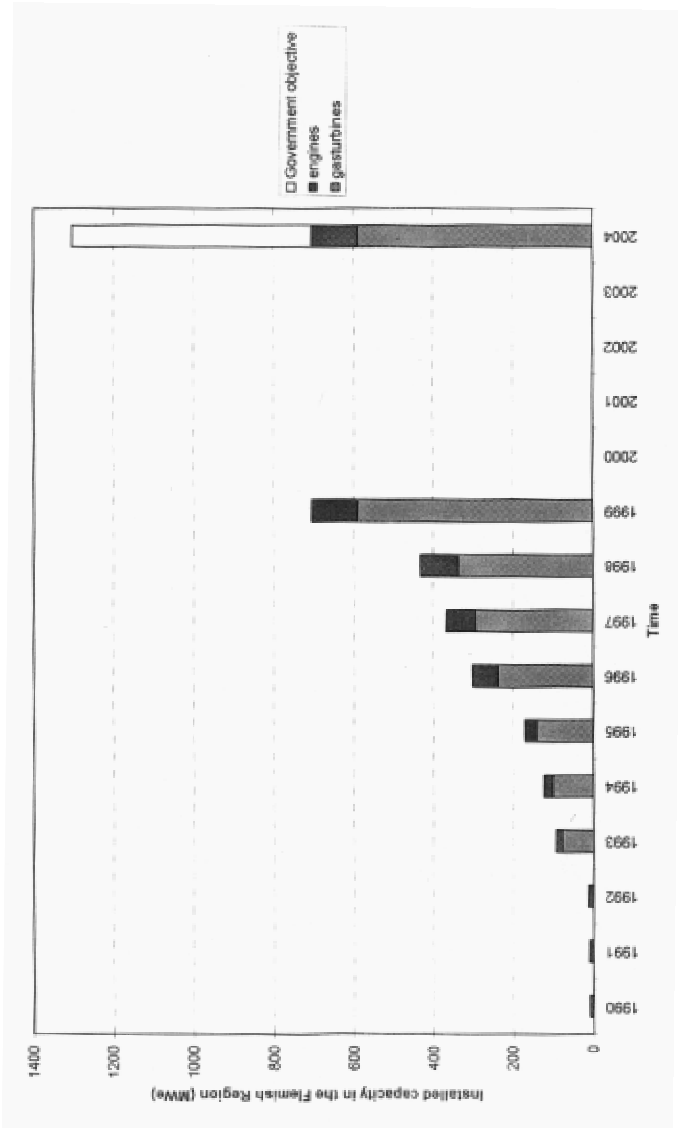


Figure 5. Cogeneration in the Flemish Region

of liberalization on cogeneration is very ambiguous. In many countries the most obstinate barriers towards cogeneration are swept away as national monopolies are taken down.

On the other hand the battle on the European electricity market implies a sharp price reduction, hampering the profitability of cogeneration. Germany for example implemented the European directives in a radical way leading to fierce competition characterized by mergers and take-overs. In this stir of the market, cogeneration is hardly viable. Also in Belgium both forces are at work, however most customers count on price reductions and choose to wait and see. From a technical point of view, biomass based cogeneration and especially mini (<20 kW,) and micro (1 kW_e) cogeneration have a lot of attention.

As a combination of cogeneration and a renewable energy source, biomass seems an attractive option for cogeneration. However, results are not clear-cut. Biomass based thermal energy production is a well-known technology with a relatively high efficiency; biomass cogeneration projects however often implicate a steam cycle based process with relatively low electrical efficiencies.

Furthermore, promoting biomass cogeneration projects results in a biomass shift towards electricity production leaving the thermal applications to be fulfilled with conventional fossil fuels. Finally, a major item regarding biomass is emission control in which cogeneration is not necessarily better. Gasification is certainly an interesting option, but the main conclusion that biomass based cogeneration projects are not necessarily better than "separate production," remains valid.

Although there are of course continuous efforts to improve the performance of turbine technology and reciprocating engines, these technologies are well-known. With mini and micro cogeneration not only new technologies but also a new market segment come on the screen.

Cogen Europe, the European cogeneration lobby, expects every residential boiler to be replaced by a cogeneration unit in the near future resulting in an enormous potential. Furthermore every swimming pool, rest home, apartment, school, etc. will be suited for a mini or micro cogeneration unit.

In the short term emphasis is still on the reciprocating engine to realize this objective, though limited electrical efficiency and emissions hamper its long-term chances. Micro turbines may be an option. At the moment fuel cells know a very animated revival for automotive as well as stationary applications. However, most technologies are still in the research-prototype phase and so there is still a long way to go.

4. CONCLUSIONS

A European overview of cogeneration is hard to give as each country has its own approach towards cogeneration. Nowadays, however, liberalization of the energy market has an overwhelming impact on cogeneration leading to price reductions and uncertainty, both making industries very reluctant to invest. At a technical level, apart from biomass based cogeneration, mini and micro cogeneration is a popular theme. Theoretically there is a huge potential for such technologies but most of them are still in the research-prototype phase.

ABOUT THE AUTHORS

Wim Luyckx and Adwin Martens are both with Vito, the Flemish Institute For Technological Research. Wim Luyckx took his degree in commercial engineering and environmental science at the University of Antwerp (1997). Adwin Martens took his degree in electrotechnical engineering at the University of Eindhoven, the Netherlands (1990). At Vito, he developed the concept of quality of cogeneration in a Belgian/ Flemish framework.

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