# EDUCOGEN

The European Education Tool on Energy-Efficiency
through the Use of Cogeneration



Group CESI


COGEN Europe


Danish Technological Institute


Hellenic CHP Association


University of Dundee


Ecotherm


ICAM


COGEN Projects


Inestene


Engineering School Mines de Douai


Catholic University of Louvain-la-Neuve


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# 1 INTRODUCTION

The Educogen project was set up to support progress towards the achievement of the EU's cogeneration target through focussing on the education and training of professionals working in this field[1]. For this reason, the project consortium brought together professionals from the educational and academic sectors from various EU Member States and a candidate country, and the European cogeneration association, COGEN Europe. A proposal on the Educogen project was awarded financial support under the contract n° XVII/4.1031/P/99-159 of the European Commission's SAVE II programme.

This report summarises the work being done within the project's framework agreed with the European Commission. It complements the two publications developed through the Educogen project which are the key result of the project, i.e. "Educogen – The European Educational Tool on Cogeneration" (2nd edition, December 2001, in this report referred to as "Educogen Tool") and "A Guide to Cogeneration" (March 2001, in this report referred to as "Guide to Cogeneration").

[1] This report generally uses the term "cogeneration". "CHP" (Combined Heat and Power), used in some expressions, such as "Hellenic CHP Association", is a synonym with exactly the same meaning.

# 2 OBJECTIVES

The development of cogeneration is important for a sustainable development of European energy production and consumption. In 1997 the European Commission published a Communication on the promotion of cogeneration, which set a target for doubling cogeneration production from 9% to 18% of European electricity generation in the period 1994 to 2010. In order to move towards this objective, and to curb energy demand, reduce green house gas emissions and market imbalances, the Commission announced on 23 October 2001 its intention to propose a Cogeneration Directive in 2002. At the date of writing this report, DG TREN is developing a draft proposal on a EU Cogeneration Directive.

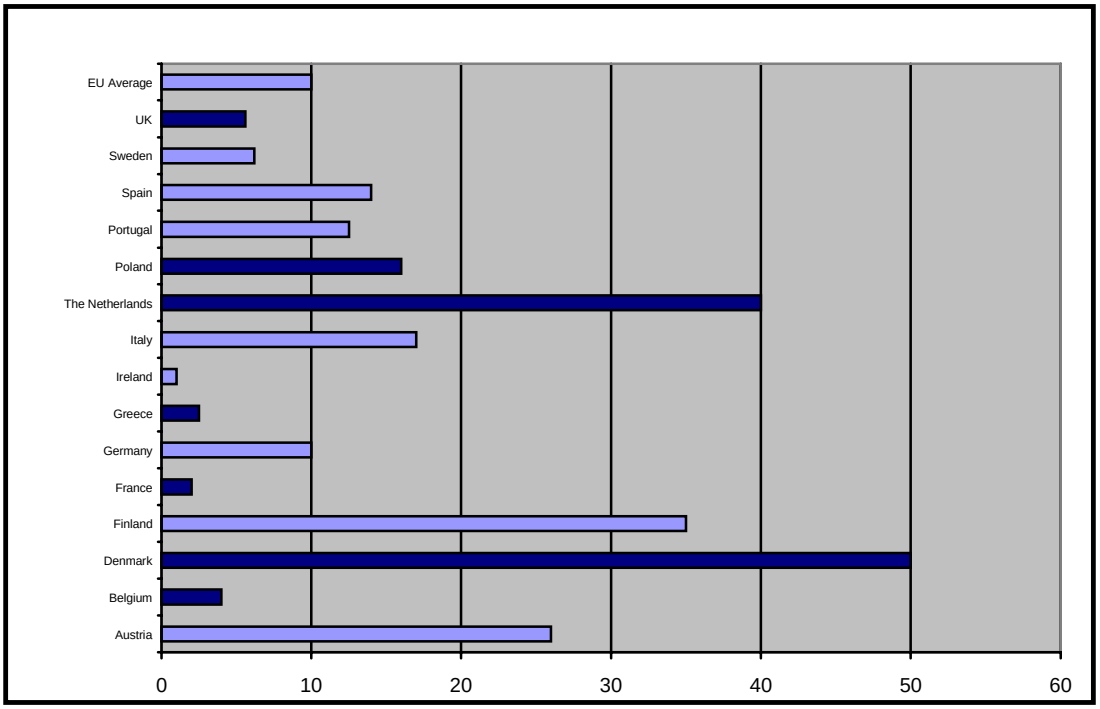


**Figure 1: Share of national electricity production coming from cogeneration in per cent in EU Members States and Poland in 1999 (Source: COGEN Europe, Educogen Partners marked in dark blue)**

An important precondition for the development of cogeneration in Europe is the availability of a sufficiently large body of skilled professionals. Some EU countries had already a good human resource base and educational activities in that respect. Yet, educational efforts occurred mostly locally, were often dispersed and were not co-ordinated at the European level.

The Educogen project aimed to address this shortcoming and help train the next generation of European engineers and technicians on cogeneration through complete educational package on energy efficiency and decentralised power production through cogeneration. The central objective of the Educogen project was therefore to

**"create a European education tool on energy-efficiency through the use of cogeneration (Combined Heat and Power), Educogen".**

This is the first attempt to create a truly European educational tool on cogeneration, including some of the most innovative technologies.

Educogen was set up with the ambition to reach more than 5000 students in at least 6 countries directly, and around 10 000 indirectly in its first year of implementation.

As a part of the broader, more comprehensive approach of Educogen comprising all cogeneration technologies in all kinds of sectors, micro-cogeneration units should allow students to actually *run* a cogeneration scheme themselves and make micro technologies familiar to them as they are coming on the market soon[2].

Educogen also wanted to include the trigeneration technique, i.e. the combined production of heat, cooling and power, given its important potential, especially in Southern Europe.

The mix of project partners should assure leaning effects, innovative potential and meaningful geographical coverage of the project. Educogen brought thus together partners from

- a country with a rich experience and high share of cogeneration (Netherlands);
- countries where cogeneration has slowly developed and where new training needs have appeared (France, Belgium);
- a cohesion country with very little cogeneration and less developed regions (Greece);
- a CEE country with experience in district heating (Poland);
- COGEN Europe, which can effectively disseminate information on Educogen through their network of members and several thousands of regular contacts.

[2] There is no common definition of micro-cogeneration units. A useful figure in a European context might be an electrical capacity of not more than 20 $kW_e$, The project did not include the purchase of these Micro-cogeneration units.

# 3 WORK PLAN AND SCHEDULE

The funding period of the Educogen extended over 25 months, between February 2000 and April 2002. During this period, the project's Work Plan listed a range of activities grouped into different phases and tasks. The project schedule in Figure 2 shows the envisaged development of the Educogen project:

Phase 1. Inception

*Task 1. Kick off (one month)*

Phase 2. Analysis and creation of the tool

*Task 2. Identification of training needs from the energy industry and training opportunities from the education community (two months)*
*Task 3. Creation of a framework for courses (4 to 5 months)*
*Task 4. Installation of micro-cogeneration units (two months)*

Phase 3. Pilot implementation of the tool

*Task 5: Theoretical sessions on the concept of cogeneration and the installed unit*
*Task 6: Practical experiments around the installed unit*
*Task 7: Analysis of case studies*

Phase 4. Evaluation of the tool

*Task 8. Evaluation work concluded by a workshop with all partners (two months)*

Phase 5. Dissemination

*Task 9. Dissemination (three months at the end of the project)*

The order of chapters in this report reflects the sequence of tasks in the Work Plan.

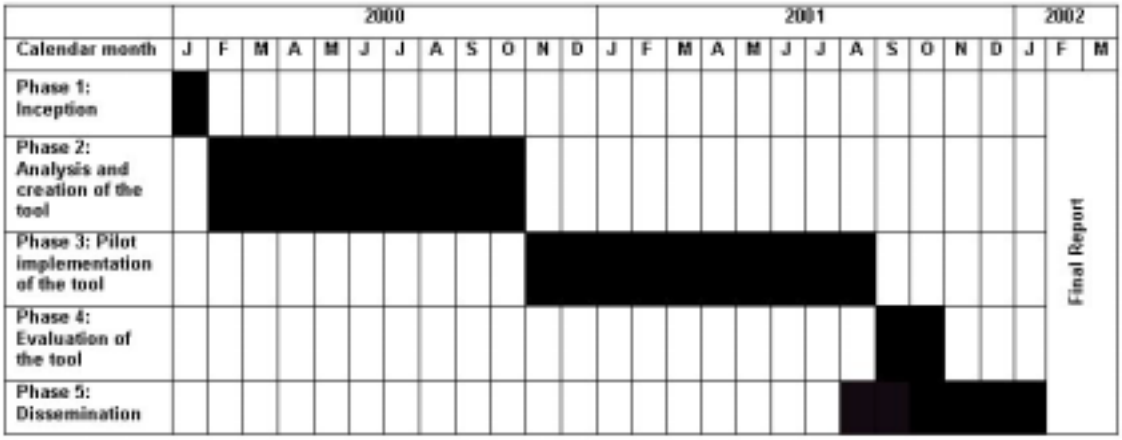


**Figure 2: Schedule of the Educogen project**

# 4 DEVELOPMENT AND OUTPUTS OF THE PROJECT

## 4.1 Analysis and Creation of the Tool

### 4.1.1 Identification of Training Needs and Opportunities

The creation of an educational tool for cogeneration requires an analysis of current and future training needs of engineers, technicians and others to meet perceived and predicted requirements in this sector. These needs, and therefore the design of tailor-made training packages adapted to meet them, vary between different countries. Before devising the educational tool, the Educogen partners therefore undertook some preliminary research on cogeneration training needs, existing training schemes, and the general profile of the educational sector in this respect.

At preliminary brainstorming session during the kick-off meeting, the Educogen partners remarked that

- there are usually no complete courses linking thermodynamics, mechanical and electrical engineering through cogeneration. The Ecole des Mines de Douai and a programme being developed at the NTUA were exceptional cases where a more comprehensive approach has been developed (see Annex 1)
- any course on cogeneration should take into account the economic and legal aspects of cogeneration;
- the EU target to double cogeneration has been widely neglected;
- initiatives are rather scattered and not linked together;

The situation in specific countries in early 2000 will be briefly described in the following chapters. A complete list of educational and training activities in some of these countries, together with details of contact persons, is presented in Annex 2 of this report.

#### 4.1.1.1 Belgium

Basic aspects related to cogeneration are part of every academic engineering programme in Belgian universities and engineering schools. However, a particular emphasis is stressed on this topic at the University of Louvaine-la-Neuve (UCL).

Additional educational activities are carried out by the main regional organisations promoting of cogeneration in Belgium, Cogensud, Belcogen and COGEN Vlaanderen. The first is active in the French-speaking part of the country, the two others in the Flemish-speaking region. They have published well-documented and useful brochures, assisting potential users to prepare pre-feasibility studies.

Large energy companies, such as Electrabel, train their own staff on cogeneration to enable them to work in this field.

The overall level of training on cogeneration in Belgium has been characterised as satisfactory. However, Belgium remains one of the countries with the lowest cogeneration

shares of total electricity production in the EU. This indicates that the political framework was not conductive to cogeneration growth so far. But it also indicates that practical experiences with concrete cogeneration installations are rather limited. It is also doubtful whether, in practice, enough engineers have been able to acquire the skills necessary to deliver the growth of cogeneration envisaged in recent government initiatives, such as green certificates in the Walloon Region, or cogeneration certificates in the Flemish region. Cogensud and UCL have been requested to provide the necessary training, and they will use the Educogen tool.

#### 4.1.1.2 Denmark

In Denmark, there is only one course on cogeneration in the Danish Technological University and the number of students is decreasing. No other Technical Universities and Technical Colleges (M.Sc. – 5 years and B.Sc. –3 years) offer special courses that particularly focus on cogeneration.

In general a student who wants to work in the field of cogeneration will follow relevant ½ year courses on e.g.: “Fundamentals of Engineering Thermodynamics”, “Thermal Power Plants”, “Gas turbines in Power Plants”, ”Energy Systems” and “Internal Combustion Engines”. Energy related studies are not as popular among engineering students (B.Sc. and M. Sc.) as they were previously and the students’ attention is now mainly paid to energy planning (to get jobs in the Danish Energy Agency, associations of power producers, grid operators etc.).

Although many students at the universities/colleges put emphasis on planning matters when doing their thesis, some students do their thesis on “hardware” related issues e.g. “Stirling based cogeneration running on biofuels”, “Micro cogeneration based on counter plunger motors” and “cogeneration running on gasification gas from wood etc.”.

In the industrial sector, at the bigger cogeneration plants skilled workers and mechanical foremen take care of the daily maintenance. Normally they will participate in different short courses:

- Skilled workers: Courses e.g.: “Cogeneration level 1” (1 week) and “Cogeneration level 2” (2 weeks).
- Mechanical foremen: Courses e.g.: “Gas-technique and maintenance of cogeneration running on gas”

The share of cogeneration in Denmark is the highest in Europe, with approximately 45% of electricity production from cogeneration. The installation and maintenance of the Danish cogeneration plant portfolio implies the availability of the necessary skills on the market. Yet, much unemployment in the energy sector has been observed in recent years. As a result, very few students choose this type of studies. This prospect hampers any deliberations on future training needs.

#### 4.1.1.3 France

Training on cogeneration is offered by a variety of actors in France.

- Information and training on cogeneration is provided by the two the two main cogeneration associations in France, ATEE (Association Technique Energie Environement) and Club cogénération:
- Cogeneration training is also carried out by the industrial and non-profit associations APAVE, ITENOR and ATG.
- In addition, specific training on cogeneration is also delivered by industry itself. EDF and GDF are the major energy undertakings with training centres for their own staff. Other large cogeneration suppliers and operators also provide technical training for their customers.
- Finally, subjects related to cogeneration are taught at Universities and Engineering Schools. The concept of cogeneration is not new, and it is linked with scientific areas taught in most of them (e.g. machinery, heat generators, heat transformer, combustion). Some Universities and Engineering Schools give their students specialised theoretical courses about cogeneration. A few of them also propose training to industrials.

Despite this apparently broad range of educational, promotional and training activities on cogeneration, an industry survey undertaken by CESI in the framework of the Educogen project revealed significant knowledge gaps. Around 30 big companies have been asked for their opinion on cogeneration training matters with the help of a short questionnaire. Almost none of the interviewees had a clear idea of what cogeneration was or whether their company had ever installed a cogeneration unit. In most big companies, cogeneration has been outsourced and is therefore not known. More precise notions of cogeneration could be only be found in those cases where own personnel is employed for the maintenance of the units. Most interviewees also associated environmental issues with constraints on their activities and reduced profits.

In general, training on cogeneration in France appears to be of an essentially theoretical nature. None of the organisations described make available training on a real cogeneration unit. Sometimes the courses are completed with a visit of a typical cogeneration facility but no experiments are made on these. It seems that only three cogeneration-units were installed at the beginning of 2000 with a training purpose in France.

Also, the socio-economic aspects of cogeneration seem to be widely neglected. These are, however, important for the viability of any concrete cogeneration project.

Like Belgium, France has a very low share of cogeneration of total electricity production, indication that the number of engineers with skills in this sector is rather limited.

#### 4.1.1.4 Greece

The development of cogeneration in Greece has been marginal so far, with only 2.5% of the electricity production in 1999 produced by cogeneration. Lack of awareness of the technology and the small number of installations mean that comprehensive training on cogeneration has not been considered by most educational institutions and organisations that potentially could provide training on this subject. Yet, the Greek legal framework has been changed in the wake of the liberalisation of the European energy markets. The new legislation, which has to be implemented during the forthcoming years, will be favourable for cogeneration and thus also for training and education on this subject.

In the Greek academic educational system, apart from the more comprehensive approach taken by Prof. Frangopoulos at NTUA (see Annex 1), cogeneration is not an independent course during the first degree in Engineering, but as part of more large subjects i.e. Thermal systems, Industrial boilers, Production of electricity, etc. At the undergraduate level, there is therefore no systematic teaching of cogeneration. Sometimes, it is only mentioned briefly in courses such as Thermodynamics or Industrial Processes.

The HACHP is trying to introduce the teaching of Cogeneration in other Engineering Schools in Greece, like the Polytechnic School of Patras and University of Thessaly in Volos, where discussions are still under way at the time of writing.

Cogeneration is taught in one of the graduate programmes for about nine teaching hours.

#### 4.1.1.5 Netherlands

No single university or school in the Netherlands could be identified that offers a particular focus – for instance through specific courses, modules or the like - on cogeneration. Activities are rather spread across a number of institutions and organisations. Sometimes, educational and training needs are also addressed through projects rather than steady courses, such as the Educogen project.

Interviews with experts give rise to the conclusion that that students should learn about the different cogeneration technologies and the concept of cogeneration. To train them on other aspects, such as the economies and profitability of cogeneration plants has been deemed less necessary during University education. It is argued that these aspects will be learnt later in the job, anyway.

#### 4.1.1.6 Poland

There are over 250 large Combine Heat and Power stations operating in Poland. These situated around all major Polish cities plants, supply heat to district heating networks. Total heat output of cogeneration is around 53 000 MW and the total length of district heating pipelines in Poland is around 13 600 km. Development of large cogeneration plants dates back in Poland to early seventies. District heating system in Krakow is a typical example a thermal energy management in the Polish cities. The 630 kilometres long district heating pipelines system is supplied with hot water/steam from two major independent cogeneration plants:

- Cogeneration plant in KRAKOW with capacity 450 MWe and 1 460 MW of thermal energy in hot water and 60 MW in steam.
- Cogeneration plant in SKAWINA with capacity 550 MWe and 300 MW of thermal output.

Those two cogeneration plants can meet approx. 68 % of a Krakow heat demand for residential heating. Currently, there are no small cogeneration plants operating in the Krakow area.

This well developed district heating systems in Polish cities require a number of professionals for development, maintenance and operation. Most of these professionals are the graduates from the Polish Technical Universities or Secondary Mechanical Schools. Curricula for these schools have been developed over years into two main, but rather separate streams:

- Demand site energy management, covering subjects concerning layouts, development and maintenance of district heating pipelines, heat exchangers stations for customers and building heating systems for heating and ventilation and sanitary hot water preparation. These subjects are mainly taught at departments of Environmental Engineering at the Technical Universities.
- Supply site energy production related to cogeneration technology, covered by courses on turbines and other types of internal combustion engines. These courses are mainly offered by Mechanical Departments of Technical Universities.

Offering training curriculum on Small Scale Cogeneration would require developing a curriculum that would combine in one-course interdisciplinary subjects on heat demand site management, and on different types of engines and gas turbines used in SSC units. Until recently such combine course is not offered to students.

The general concept of cogeneration technology in Poland is associated with large-scale cogeneration based mainly on fossil fuel boilers that are common in most of the Polish cities. The training would have to disseminate the concept that a small-scale cogeneration is an economically and environmentally sound solution not only for big companies that operate on M We basis but also for small businesses and communities that have energy needs in terms of tens or hundreds of Kilo Watts. The training should include examples of successfully installations that were commissions in different countries thought EU as live examples of benefits arriving from small-scale cogeneration technology. The important part of the training should be not only sole technical aspect of the cogeneration unit but also the economics of including feasibility, pay-back and other finances issues.

#### 4.1.1.7 United Kingdom

At this time, cogeneration training in the UK is sparse and fragmented. Despite a review of government agencies, manufacturers, contractors, users and educational establishments, the courses listed in Annex 2 are the total found to date.

Although there are some courses in the UK that target specific skill requirements such as gas turbine operation, and courses which study general energy topics, there is a shortage of training in the complete range of skills needed for a cogeneration manager. There is a

problem in establishing a viable market value of such a training programme, as the need is not yet widely perceived.

Mostly training is in the form of short courses (2 days to 1 week) often directed towards maintenance and general operation, rather than teaching the principles of cogeneration, or how to design and install such plant, or carry out a financial appraisal.

These courses are also generally of a mechanical nature, and directed towards particular topics of engines or turbines, with little emphasis on the electrical or overall performance of the system.

Several universities included the topic of cogeneration in courses such as Electrical or Mechanical Engineering, or Environmental Energy Technology, usually at Master's level.

However moves by the UK government to implement Kyoto through the Climate Change Levy will mean that some industrial and other sectors that are not yet involved with cogeneration will have to move in this direction for economic reasons.

#### 4.1.1.8 Conclusions

The analysis and evaluation of training needs and existing training schemes on cogeneration gave rise to the following conclusion:

- Complete university courses on cogeneration that cover all relevant technical aspects (thermodynamics, mechanical and electrical engineering) do generally not exist. The school of Armines and NTUA were exceptional cases where a more comprehensive approach has been developed.
- Students should obtain a general feeling of cogeneration technologies and the different applications, but there is no need to go very deep. Most big cogeneration companies offer specific training courses for their employees adapted to their particular technologies and applications. They want universities to provide students with basic knowledge, which later can be fine-tuned in the job.
- In addition to the technical aspects, any course on cogeneration should include the economic and legal aspects of cogeneration. These aspects are arguably less important for the academic career, yet they are crucial for the viability of any development of cogeneration projects. Understanding the viability
- Training on cogeneration should have a promotional character, given the economic, social and environmental benefits of cogeneration. The EU target to double cogeneration from 9% to 18% of total electricity production between 1990-2010 has been widely neglected, and some Educogen partners work in countries with extremely low percentages of cogeneration. In Poland, the training would have to make clear that a small-scale cogeneration is an economically and environmentally sound solution not only for big companies that operate large units, but also for small businesses and communities that have energy needs in terms of tens or hundreds of kilowatts. The training should also include examples of successfully installations in different countries, as a showcase of the benefits arriving from small-scale cogeneration technology.
- The promotional effects of training on cogeneration are also justified on the grounds that these will have an influence on political and legal frameworks. For instance, there is little

use in launching a detailed debate on training needs in Greece as long as the political and legal framework does not encourage the development of cogeneration. Training and education therefore would first of all need to motivate decision makers to create an adequate framework. This framework would then result in a higher demand for training of engineers to meet the demand for high-quality cogeneration installations. The provision of training on cogeneration and the development of cogeneration capacity are therefore mutually reinforcing.

- To satisfy both the demand for detailed knowledge and "easily digestible" explanations on cogeneration, two different modules or tools could be developed, one for undergraduate students and anybody with an interest in cogeneration, and another version for those who require more detailed insight, such as graduate students, teachers, trainers etc.
- Education and training activities on cogeneration in different countries, and within countries, are not sufficiently linked together. There is a need for more exchange and networking.
- Any training module or tool on cogeneration should allow for some flexibility, because the training needs to be adapted to the specificities in each country, and to the needs of each user group (university students, practitioners, etc.). The organisation of the training material in the form of a reference book would therefore be very useful, because teachers could use this in a "pick-and-mix" style.

### 4.1.2 Creation of the Educogen Tool

Taking into account the conclusions presented in the last chapter, and considering the practical experience of the Educogen partners working in the educational sector, a framework for training was to be created. The project partners agreed that the educational tool to be developed should consist of two parts:

- An introductory course (around 15 hours) for students that have not yet finished the basic technical studies but before specialization. It should also be of wider use for anybody interested in cogeneration.
- A ‘full’ course for students with enough technical background - usually around 4 years after bachelor - and experts, teachers, etc.

The introductory course should feature courses on

- The technology (prime mover, fuels, combustion, transformation for fuel cells, alternator/generator, control systems, heat load and electricity)
- The legal framework (buy-back regimes, authorization and licensing, and environmental aspects such as emissions, permits, emission credits or fees)
- The economics of cogeneration (economic feasibility, pay-back, ownership and financial issues)

The use of existing material was considered a good way of going about the creation of the Educogen tool. The project partners agreed therefore to start on the basis of the programme

of Prof. Christos Frangopoulos of the National Technical University of Athens (NTUA), which would then be completed by contributions from all partners.

As a result, a full course with plenty of detail - dubbed the "Educogen Tool" - and a short version – called the “Guide to Cogeneration” were developed. Both can be used as academic teaching material for. The number of hours available, and the level of knowledge aimed at will determine the choice between the two.

The Educogen Tool has been based on the course used by the National Technical University of Athens, with comments and many additions provided by the partners of the project.

The Cogeneration Guide has been written by COGEN Europe. Other partners have contributed through their comments.

Copies of the "Educogen Tool" and the “Guide to Cogeneration” are provided in the Annexes 3 and 4 to this report.


**Figure 3: The "Educogen Tool" (the full training module on cogeneration, second edition from December 2001, see Annex 3)**


**Figure 4: The "Guide to Cogeneration" (the short training module on cogeneration, first edition from March 2001, see Annex 4)**

### 4.1.3 Installation of micro-cogeneration units

Closely related to the Educogen project, the installation of four micro-cogeneration units (Dundee, CESI, UCL and Athens) in addition to an already existing unit in Douai was envisaged. The money necessary for their purchase and installation could, however, not be included into the project's budget because the SAVE programme explicitly centres on non-technical action on energy efficiency. The partners wanting to install a unit therefore relied on other funding sources for this part of the project. This dependence on additional funds made this part of the project less predictable than other parts. The current situation is as follows:

- UCL was granted financial support from the Walloon region to purchase a 5-kWe micro-cogeneration unit from Ecopower, installed in autumn 2001. The order of a Stirling engine is envisaged. UCL also has an agreement with Katholieke Universiteit Leuven (KUL) to use their micro-cogeneration unit, a Senertec engine.
- The University of Krakow has a landfill cogeneration unit.
- The Technical University of Athens already uses a medium-scale cogeneration unit.
- The University of Utrecht runs two cogeneration units that they visit during the lectures.
- Dundee University had already cogeneration engines from Jenbacher, which were purchased and are operated through the "Dundee University Utility Supply Company (DUUSCo)". The University was in negotiations with Whispers to get a demonstration micro-cogeneration unit.


**Reciprocating Cogeneration Engine Unit (Ecopower)**

**Reciprocating Cogeneration Engine Unit (SenerTec)**

**Reciprocating Cogeneration Engine (Jenbacher)**

**Stirling Cogeneration Unit (Whisper Tech)**

**Figure 5: Different types of cogeneration units to be used by the Educogen partners. Their installation is partly done, partly envisaged.**

## 4.2 Pilot Implementation of the Tool

The following chapters present the various activities undertaken by the Educogen partners with the aim to bring the Educogen Tool and the Guide to Cogeneration to use, and to embed their application in broader training, education, awareness raising and networking activities.

### 4.2.1 Theoretical sessions on the concept of cogeneration and the installed unit

This part of the project aimed to embed the training on cogeneration into a broader action on energy-efficiency for each university/training body - ideally a real information campaign reaching out into all departments and areas of the organisation, and familiarising students with the relevant concepts.

#### 4.2.1.1 Belgium

In terms of a broader initiative for energy efficiency, UCL offered in the framework of the most advanced course for (electrical-) mechanical engineers during the autumn semester 2001 two lectures of hours duration exclusively dedicated to cogeneration systems. A broad range of equipment sizes has been explored. A third lecture was dedicated to medium-sized trigeneration systems.

The theoretical session on cogeneration has the name “MECA 2150 – Cycles thermiques”. 35 students in their 4th year (engineering degree) participated in 30 hours theory and 30 hours exercises and site visits. A webpage has been created on http://www.term.ucl.ac.be/cours/meca2150/.

The course included the thermodynamic characterization and optimisation of several types of cogeneration systems (steam cycles, gas turbines cycles and IC engines) and of an evaluation of performance indices, energy savings, and environmental impacts. Local and European issues were touched upon through a brief description of the current legal framework (quality cogeneration, "green certificates" market for cogeneration).

The Educogen Tool has been as a complement to the basic course, which provides thermodynamic approach and methodology. A link to the Educogen webpage has been created on the website for the course, encouraging students to download the Educogen Tool. Other material used included:

- The basic course, thermodynamically oriented and recent research results in the field of trigeneration.
- "La petite cogénération, Pour qui? Pour quoi?” COGENSUD, 1997[3]

The course resulted in a good knowledge of the field, on the basis of an extended course material.

#### 4.2.1.2 Denmark

As DTI is not a university they do not normally have students or teaching activity. Yet DTI works in close co-operation with Danish Technical University.

DTI’s activities centred mainly on an exchange student from the Educogen partner form Dundee. This student did his MSc thesis at DTI and the Danish Technical University.

#### 4.2.1.3 France

Ecole des Mines de DOUAI

As a broader initiative for energy efficiency, within which task 5 activities occurred, a Conference on Cogeneration, Energy and Environment was performed at *l’Ecole des Mines de Douai* on 29 November 2000. This conference gathered students of the second, third and fourth years of *Ecole des mines de Douai*. Students from ICAM and CESI were also invited. The presentations were performed by Educogen partner and also by two people from

[3] http://www.iwallon.be/cogensud/pages/pubfra.htm

industries directly linked with energy and cogeneration (ELYO and Gaz de France). This conference was open to everyone, and an information campaign was made in order to gather the maximum number of people. An article was written for the school newspaper (1000 readers, see Figure 6), the conference program was published on the school website, and an email was sent to about 350 human resources managers from industry. The conference programme is provided in Annex 5 to this report.


Porte Mines
N°295

**Figure 6: Article in the School newspaper of Ecole des Mines de Douai about the Educogen Conference**

With respect to the courses on cogeneration, energy-efficiency and environmental aspects of the use of energy, two different modules are offered:

- A cogeneration course describing clearly the main aspects of cogeneration (technical, economical)
- A group of different courses directly linked with cogeneration in which technologies of cogeneration, economic aspects and environmental impact of the efficient use of energy are treated

On the cogeneration course, in 2001 it involved 25 students in their 4th (and last) academic year. The teacher is an EDF-GDF expert engineer in cogeneration study. The European aspects of cogeneration are treated in a comprehensive way. The course follows the following table of contents:

**1 - COGENERATION PRESENTATION**

Definition
Technical point of view

**2 - Advantages of cogeneration**

Energy saving
Environmental aspect
Versatile fuel
An efficient concept opened to a great amount of applications

**3 – French market of cogeneration**

French pool of cogeneration unit
Kind of technology
Power consumption
Industrial sector

**4 – Cogeneration in Europe**

Introduction
Dutch cogeneration
The German case
Cogeneration in Portugal
The Italian case
The growing Spanish cogeneration market
The Swedish case
Cogeneration in England
Other European countries
French market
European market

**6 – Cogeneration using fuel cells unit**

Working principle
Advantages

**7 – The dimensioning problem**

Legal framework
Economic framework
Dimensioning of cogeneration units

**5 – Cogeneration applications**

The course was held from the 12-26 January 2001. The Educogen Tool was not directly used in this course but it was given to the teacher to use it as he considers suitable. Each student was told they could have a copy of the Educogen main course. Moreover during the conference of the 11/29/2000 a copy of the Educogen guide was given to every student attending the conference.

At the end of each school year, a meeting gathers all the students of the Industrial Energy Department, the director of the department and the person in charge of the organisation of the courses. The cogeneration course has received a positive return from the student and this course is therefore maintained for next year (2001-2002).

Apart from this main course on cogeneration, there are 3 more courses which are linked to the subject:

- Energétique des machines (thermodynamics and Machinery) 28h – fourth year study in energy department – 25 students. Contents: fundamentals of thermodynamics (cycle, thermodynamics principles...) machinery (gas turbine, steam turbine...).
- Maitrise et gestion de l'énergie (efficient use of energy) (new course) 17h 30 – fourth year study open to student from other departments of the school – 25 students. Contents: Financial aspects of the use of energy, analyse of energy sources in the industries, optimisation of energy uses...
- Combustion
  17h 30 – fourth year study open to student from other departments of the school – 25 students. Contents: Production of heat from combustibles

The three courses have been received positively by the students and are maintained for next year (2001-2002). The course of efficient use of energy was new from this year.

ICAM

The course reached under the title "La cogénération" addressed 100 students in the 2nd year of their engineering degree and had a duration of 4 hours. It comprised a presentation of the different cogeneration technologies, the environmental benefits of cogeneration, and its economic and legal aspects. As a result of the course, the students became aware of cogeneration and its contribution to energy-friendly energy policies.

A French summary of the Educogen Tool has been created to support the course. It was used as presentation material and it has also been made available on the Educogen webpage, from where it has been downloaded more than 1000 times by February 2002.

In addition to the ICAM course, 50 students attended the Educogen conference held in Douai (see chapter 4.4.3). This helped them obtain information on cogeneration in the wider European context.

CESI Engineering School

A master degree on environmental studies has been developed. The Educogen Tool is been studied so that it can be used as a background material in a course on energy efficiency. Enrolments should normally start in the next academic year.

The Educogen Tool has been used as a reference material in the Solar Energies course (School of Engineering in Paris). Emphasis is placed on energy efficiency and environmental implications in a global point of view. Cogeneration is one of the technologies developed in the course to make future engineers aware of what is available. There were 120 students, 4 hours lectures on the topic and one lecturer concerned for last academic year.

The Educogen Tool has been used as background material for student's projects within the school or in companies. Following the conference in Douai, 7 students made their first year research project on cogeneration (both technical and economical assessment aspects of the technology has been studied). 6 students made a 'scientific study' on cogeneration and/or cogeneration units in their companies (Dalkia, EDF, GDF, Teta, ADEME and Novergie). The philosophy of this study was to solve a technical problem for the company. Each of these projects ended with a written report and an oral presentation before an examination board.

The Educogen Tool has been copied (50 copies) and disseminated in all the CESI schools of engineering in France (12 schools, 1300 engineering students and 1500 associated lecturers) where it has been placed at the disposal of all students and lecturers in libraries. The copies are available to both technical and non-technical students in each of the 24 schools of engineering in France. However, it is not possible to tell to what extent the Tool has been used so far.

To date, the Educogen Tool has been used as a background material in the CESI school of engineering in Paris in relation to courses on “Thermal physics” and “Solar Energies”. 240 students in the 1$^{st}$ and 2$^{nd}$ year of their engineering degree attended between 6 and 8 hours on the topic for both courses during the last academic year. The course on Thermal physics aimed to elaborate on the technical aspects of a cogeneration unit and on energy efficiency. The Solar Energies course looked at different sorts of renewable energy sources. Cogeneration and the technology available are studied as one of them.

In addition to these courses, the Educogen Tool has been used to support individual research projects and scientific studies, each with a duration of app. 6 months. Altogether, 13 students were involved.

Within the research projects (1$^{st}$ year engineering students) the Tool has been used to study the concepts of cogeneration from a technical and economical point of view. These projects work was carried out at school. The students had to learn to understand the technical features of a cogeneration unit, different technologies available, the concept of energy

efficiency, and environmental implications. They had to make a report and present their work before an examination board.

The scientific studies (2nd and 3rd year engineering students) covered different subjects, but all aimed to solve a technical problem and find a solution that would suit the company's needs: To study and to demonstrate the technical and economical feasibility of an ethanol Fuel cells system for cogeneration units; to study and assess different cogeneration units to find one that would match specific needs; to solve heat problems within the company cogeneration units; to study and optimise cogeneration systems to match specific needs. Unlike the research projects they were undertaken in companies.

#### 4.2.1.4 Greece

In Greece, the Educogen Tool was not only used by students, but also by a large number of the members of HACHP involved in proposals related to cogeneration which they submitted within the 3rd framework of the European Cohesion Funds. According to their opinions, the Tool proved to be of great support for them.

HACHP is disseminating the Tool through 3 courses and presentations to engineering students and young unemployed engineers:

- The first course, in Iraklion Crete, was titled 'Energy Efficiency, Renewable Energy Sources and Cogeneration" and it was designed for young unemployed engineers (summer 2001). It involved 20 students.
- The second presentation is to be given to 30 graduate students of the Mechanical Engineering Department of Thessaly University at Volos (winter 2001-2002).
- The third presentation is to be given to the 30 final-year students of the Energy Department of the Technological Institute of Athens (winter 2001-2002)

To all these seminars and presentations, all chapters of the Tool were presented analytically, with discussion, where questions were answered. In Addition, the existing book on cogeneration in Greek language was used, and the new energy law and the existing situation in Energy after liberalization were presented. This provided young engineers as well as scientists working in the subject with a background in cogeneration.

Also, more than 100 members of the Hellenic Association for Cogeneration of Heat and Power were informed that the material of Educogen was placed on COGEN Europe's website, and those without any access to the internet were given a CD ROM with the material.

Practical experiments around an installed unit and analysis of case studies could, at the time of writing, not be accomplished in Greece.

#### 4.2.1.5 Netherlands

COGEN Projects was involved in a course called *Innovatieproject 3* (Innovation Project 3) provided at the University of Utrecht, Department for Natural Science and Innovation Management. In this course, students obtain lectures on innovation in cogeneration,

biotechnology and infrastructure. This includes two lectures on each of the three different areas. In, addition, 5 lectures about innovation theory in general are provided.

In total, 25 students attended the course in, 12 of which with a specific focus on the cogeneration area. These participate in two lectures on micro-cogeneration and the possibilities in the Netherlands. The first lecture described cogeneration in the Dutch situation, the principles of cogeneration, involved parties in micro-cogeneration and economic aspects of micro-cogeneration. The second lecture described the technical opportunities and technical problems for micro-cogeneration. Two groups made an analysis of the possibilities of micro-cogeneration in the Netherlands. Both group had a different technology and had to represent a company (Vaillant and Atag).

The Educogen Tool was used as a reference book.

#### 4.2.1.6 Poland

The University of Krakow's Department of Thermal Engineering has agreed to integrate cogeneration into three different modules, each with duration of 15-20 hours and involving between 40 and 200 students (3rd year undergraduate or 4th year master degree, Department of Environmental Engineering):

- (*Gospodarka cieplna*) Thermal energy management
- (Wykorzystanie energii odnawialnej) –Use of renewable energy
- (*Centrale i sieci cieplne*) Boiler houses and district heating

These three courses are designed to provide the students with a broad knowledge of energy management, its technical aspects and diversified energy sources with special emphasis to renewable energy. Energy systems are related closely to local and global contents including recent EC legislation. The products of the Educogen project were widely used:

- The Educogen Main Tool was used for master level Engineering students
- The Educogen Guide was used for undergraduate students as introductory lectures
- COGEN Master was used for specialization curses for students with diploma specialization in thermal energy management
- The Educogen website was recommended to students who had to do assignments at home

Other educational and training material included:

- F. William Payne Cogeneration Management Reference Guide, the Fairmont Press Inc. 1997
- Scott A. Spiewak, Larry Weiss Cogeneration and Small Power Production Manual, The Fairmont Press, inc 1997

#### 4.2.1.7 United Kingdom

The Educogen documentation and concepts have been made available to members of the classes in Power Engineering (undergraduate level) and MSc/Diploma in Electrical Power Engineering & Management (postgraduate level)

Regrettably, the University of Dundee was not able to consider a broader initiative for energy efficiency and theoretical sessions to support the pilot implementation phase.

Yet, the Educogen documentation and concepts have been made available to members of the classes in Power Engineering (undergraduate level) and MSc/Diploma in Electrical Power Engineering & Management (postgraduate level).

In addition an MSc student from Dundee ( a Greek student) has been carrying out his project with the Danish Technological Institute on their cogeneration equipment.

### 4.2.2 Practical experiments around the installed unit

This part of the project aimed to develop a framework to carry out practical experiments on each prime mover selected, i.e. Stirling engine, small gas engine, etc. Trainees should not be restricted to one technology. This task ideally would, for each Educogen partner, comprise of

- an analysis of all technical features of the cogeneration unit;
- analysis of the efficiency of the unit;
- analysis of the emissions coming from the exhaust of the unit;
- analysis of the impact of load requirements onto the micro-cogeneration unit.

This framework needed to be adapted to the specific local circumstances.

#### 4.2.2.1 Belgium

UCL carried out a series of two practical experiments around the installed unit.

The first experiment concerned a district heating system in Louvain-la-Neuve, run with a 10 $MW_e$ gas engine cogeneration unit (Electrabel, Dalkia). The 35 students following the theoretical sessions on cogeneration were involved in this exercise of 2 hours duration which was organised by UCL in co-operation with Electrabel and occurred in 1999, 2000 and 2001. It consisted of a presentation of the design and energy balance of the unit, its environmental impacts, and its profitability, plus a one-hour site visit. The presentation of different cogeneration technologies followed the approach taken during the theoretical sessions (task 5), including:

- Analysis of all technical features of the cogeneration unit: IC engine, heat exchangers, and hydraulic connections…
- Analysis of the efficiency of the unit: annual energy savings, part load performances…
- Analysis of the unit's emissions: $NO_x$ and CO emissions
- Analysis of the impact of local requirements on the cogeneration unit: grid connections, gas connections, integrating in the existing boiler house.

Some figures related to cogeneration systems based on IC engine (chap. 3) and references to economic analysis (chap.6) provided in the Educogen Tool were used during this exercise.

The second experiment carried out by UCL will be on their own micro-cogeneration unit, a 5-$kW_e$ gas engine from ECOPOWER, which has been purchased in 2001. It will be in operation for practical training from January 2002. The experiment will involve the same group of students as described above, and it will have a similar approach, focussing on the energy balance of the unit, environmental impacts, and its profitability.

Again, input into the experiment was obtained from the Educogen Tool, e.g. figures related to cogeneration systems based on IC engine (chap. 3) and references to design methodology (chap. 7) and economic analysis (chap.6).

In relation to both experiments, an on-line presentation of the cogeneration units has been provided on http://www.meca.ucl.ac.be/term/cours/meca2150/cogenLLN.htm, and on-line access to Electrabel monitoring system was also facilitated.

#### 4.2.2.2 Denmark

In terms of practical experiments, during 3 years, DTI has participated with an own test-site in a national project where 10 micro-cogeneration demonstration installations have been tested. The micro-cogeneration technology was rather new in Denmark, when the power companies wished to test the units for future implementation in the power production.

One micro-cogeneration unit based on LPG gas was installed at DTI and has been in operation for more than 2 years. Specifically has the unit has been in operation of app. 3800 hours in 2 heating seasons. The unit installed at DTI is a traditional combustion engine, but it is expected that during the next couple of months different technologies like sterling engine and fuel cell driven cogeneration will be tested.

The main purpose was to test the reliability of micro-cogeneration in a national power grid. The operation, efficiency, start stop, heat load etc was analysed. In two years the engine has had app. 12.000 start/stops, the power efficiency is app. 25%, the heat efficiency is app. 86%, there has been no other maintenance on the unit than yearly replacement of spark plugs, strainers and oil. The analysis included the following steps:

- Analysis of all technical features of the cogeneration unit: The main purpose was to test the reliability of micro-cogeneration in a national power grid. The operation, efficiency, start stop, heat load etc was analysed. In two years the engine has had app. 12.000 start/stops, the power efficiency is app. 25%, the heat efficiency is app. 86%, there has been no other maintenance on the unit than yearly replacement of spark plugs, strainers and oil.
- Analysis of the efficiency of the unit: As stated above the power efficiency is app. 25% and the heat efficiency is app. 86%. Unfortunately the heat load or heat demand at DTI has been rather low in the period, thus the unit has had to large a capacity resulting in many start/stops.
- Analysis of the unit's emissions: The emissions on the unit have not been analysed continuously, but frequent measurements showed that the emission from the unit was within the Danish rules for emission.

- Analysis of the impact of local requirements on the cogeneration unit: The Danish Power company called NESA has used the unit at DTI to analyse the possibility to implement micro-cogeneration units in their grid. As part of these analyses the impact of local requirements has been dealt with, but the results are not public.

Based on the experiments and the ongoing projects in Denmark several brochures promoting micro-cogeneration have been published. The 7 brochures are dealing with

- heat load and power load profiles
- marked segment for micro-cogeneration
- control strategy
- suppliers of micro-cogeneration units
- guidelines for installation
- rules, norms and standards
- technology catalogue

#### 4.2.2.3 France

Ecole des Mines de Douai

Practical experiments are undertaken under the heading "*Travaux pratiques sur la Plate Forme Energie"* (practical work on the energy platform). 25 own 16 students from the "Ecole des mines d'Albi are involved in this four-day exercise package about cogeneration.

The cogeneration unit used is a steam installation with a 600 kW boiler, a small steam turbine about 15 kW, an electric super heater, a heating unit with a pressurised water circuit and two water circuits, two combustion test bench. All the equipment is industrial equipment, and many different measurement systems are placed at strategic locations. The training on this unit is divided in several practical experiments:

- Combustion study: natural Gas combustion study on a small boiler.
- Study of an industrial boiler: Thermal study of an industrial boiler.
- Heat exchanger: Heat transfer study of a steam/water industrial heat exchanger.
- Fuel oil boiler: Thermal and hydraulic study of small fuel oil boiler.
- Flame front propagation: Measurements of a flame front velocity.
- Digital regulation: Study of an industrial digital regulation system.
- Urban heating unit: Thermal study of urban heating unit.
- Turbine: Study of a steam turbine
- Cogeneration: Study of the behaviour of a cogeneration unit.

The practical experiment is an illustration of the theoretical course presented in the last chapter. There is no particular need to again explain the different cogeneration technologies. Still, during the practical experiment a particular exercise is to present the different efficiency

of the whole installation and during this exercise the different types of cogeneration unit are briefly recalled.

In accordance with the Educogen work plan, the experiments cover aspects of cogeneration units such as the analysis of all technical features, the efficiency, and the emissions of the cogeneration unit.

ICAM

Experiments at ICAM focussed on the engine, generator and heat exchanger of cogeneration units. The 4 hours of practical experiment offered to 100 students in the 1st and 2nd year of their engineering degree complement the theoretical courses on thermodynamics, electrical engineering, and heat transfer. The students attend thus a theoretical course and are then involved in a practical experiment. The specific value of the cogeneration course is its holistic approach. Previously, students had knowledge on individual elements that form part of a cogeneration unit, however, without being aware of the cogeneration unit as a whole and without knowing how exactly such a unit works.

The experiments included an analysis of all technical features and the efficiency of the cogeneration, focussing on the individual parts/technologies combined within a cogeneration unit. 20 students, who have done the case studies described in the next chapter, have visited the cogeneration unit that they have analysed.

CESI

Within the framework of scientific studies, 6 students had to solve a specific technical problem of the cogeneration units in their company. They had to study the subject from a theoretical and practical point of view, and to design a suitable solution that would match the company's needs

#### 4.2.2.4 Poland

Practical experiments were related to specialization curses for students with diploma specialization in thermal energy management. And experimental laboratory on a 250 $kW_e$ cogeneration unit installed at the Krakow landfill site was organised. It had a duration of 3 hours and involved 60 students on a MSc course.

The students visited the cogeneration unit. A presentation divided into a presentation of biogas collection, storage and supply system at the landfill, and a presentation of the cogeneration unit with its main components: prime mover, power generator, heat recovery system and control. In the practical exercise, the main focus was on different options for fuel sources for the cogeneration unit. Those covered were mainly landfill gas, sewage treatment plant biogas, and natural gas or LPG.

The experiments include the following elements:

- Analysis of all technical features of the cogeneration unit: Students were asked to identify all main components of the cogeneration unit and its heat and power external installation.
- Analysis of the efficiency of the unit: To calculate energy efficiency of the cogeneration unit students performed measurements with portable RTD type thermometer and clamp

on amperes meter. Additional information e.g. on fluid flow rates gas consumption etc. necessary for calculation are read from computerised control panel of the unit.

- Analysis of the unit's emissions: Students do the calculation of emission from the engine and asses avoided emissions from the landfill and avoided emission of CO2 due to the electricity and heat produced by the cogeneration
- Analysis of the impact of local requirements on the cogeneration unit: Since at the moment overproduction of heat occurs during most of the operation time of the unit, the students were asked to elaborate on investments that could associate with the unit to make it possible better utilise thermal energy for cogeneration (e.g. green houses, wood dryer etc.)

The Educogen Tool and other materials from the project were used as introductory material to students who are to prepare different aspects of cogeneration related to this practical exercise.

#### 4.2.2.5 United Kingdom

At the University of Dundee, as part of a MSc, a student undertook a so-called "Control Strategy Evaluation and Market Potential of Inverter Driven Micro Combined Heat and Power Units". The dissertation was be available to the Educogen website, from where it had been downloaded 170 times by February 2002.

### 4.2.3 Analysis of case studies

#### 4.2.3.1 Belgium

Case studies were carried out at UCL in the framework of the regular course described above, and through individual theses for the MSc degree.

In terms of the regular course work during the academic year 2001-2002, the students undertook case studies on two cogeneration units:

- 25 MW gas turbine cogeneration units (Electrabel – Vandmoortele, Izegem, Belgium)
- Gas-engine trigeneration unit (ERASME Hospital, Belgium)

The case studies centred on

- Heat, cold and electricity load curves identification
- Design and techno-economic optimisation,
- Energy balance, performances indexes, profitability
- On site visit (trigeneration unit only)

The case studies included the following analytical steps:

- Technical analysis of the energy needs of units examined through load curves
- Economical analysis of the units examined through a discounted cash-flow method

- Environmental impact assessment through analysis of CO2 savings, CO, and $NO_x$
- Pricing analysis of the current tariffs and energy supplies including the green certificates market

Demand side management options were systematically explored on the basis of several examples made available from a research project dedicated to trigeneration.

The Educogen Tool was used together with a basic course of thermodynamic, the COGENSUD guide, and: research results from project "Connaissance des émissions de CO2" financed by Electrabel and SPE.

A webpage on http://www.term.ucl.ac.be/termwww/cours/meca2150/tp.html has been created to support the case study analysis.

Case studies in the framework of MSc thesis work in 2000-01 included the “Design and profitability analysis of a trigeneration unit at Mont-Godinne Hospital, Belgium” and a “Domestic micro-cogeneration analysis”. Four students in the 4th year of their engineering degree were involved. Their work comprised of the following areas:

- Energy demand curves identification/modelling
- Optimal design and operation (e.g. thermal storage)
- Energy balance, performances indices, profitability
- Sensitivity and risk analysis

The case studies included the following analytical steps:

- Technical analysis of the energy needs of units examined through load curves
- Economical analysis of the units examined through a discounted cash-flow method and a real options method
- Environmental impact assessment through analysis of CO2 savings, CO, and NOx
- Pricing analysis of the current tariffs and energy supplies including the green certificates market

Demand side management options were systematically explored on the basis of several examples made available from research projects dedicated to trigeneration, and on the basis of studies performed by the division Architecture & Climate from UCL.

The Educogen guide has been given to the students as a reference book (mainly Chapter 4 to 6[4]). Additional material used included research results from projects "Connaissance des émissions de $CO_2$", financed by Electrabel and SPE, and "MICRO" financed by the Walloon Region.

[4] First edition of the Educogen Tool

#### 4.2.3.2 Denmark

DTI supervised an MSc student on exchange from University of Dundee. His thesis "Strategy Evaluation & Market Potential of Inverter Driven Micro-Cogeneration Units" took 4 months. It started with an investigation on cogeneration in Denmark and other EU countries from a financial, technical and political view.

The student knew the Educogen tool and the guide from Dr. Bruce Ramsey in Dundee, and used them during the period. Furthermore he promoted the tool and the guideline during his work with different companies, energy supply companies and other students. Additional training material from the Danish Energy Agency, DTI and especially the website of the Energy Centre Denmark[5] were used.

As part of the thesis study measurements were made on 2 micro-cogeneration units. The measurements were used for performing statistical computer models of the units. These experiments were performed in co-operation with Danish Gas Technological Center, and were focused on different load strategies in order to get statistical data for the computer models. The tariff structure, pay back time etc. was calculated in order to analyse the feasibility of micro-cogeneration units in Danish households outside the national gas network and DH systems. The data from the experiments are not public.

The final results of the thesis were mainly guidelines for operation of cogeneration units based on the tariff structure in Denmark.

Furthermore it is expected that a micro-cogeneration unit based on a sterling engine or fuel cells will be tested in the lab at DTI in near future. If students would have an interest the testing could be part of their study.

#### 4.2.3.3 France

Ecole des Mines de Douai

No case study has been included yet in the course of cogeneration; but each year about 15-20 % of the students in their 3rd or 4th year of study make a training period in industry with a subject directly linked with cogeneration. All of them are provided with the Educogen Tool.

ICAM

At ICAM, 10 cogeneration units have been analysed during the course, including the *Piscine Max Dormoy*, *Lycée Gustave Eiffel*, *Réseau de chaleur de Roubaix*, *Hopital de Lens*, and *Usine Cerestar*. The case studies were prepared through a short introduction which partly used the Educogen tool. Each case study was completed by two students who presented their results to the whole course through a document and a Power Point Presentation. The students have to identify a cogeneration and then to perform a technical and economical analysis of it. A technical analysis of the energy needs of units examined was generally included. The scope of this analysis could, however, vary from case to case. Also, some students have in their case studies chosen rather to focus on the economic aspects of the cogeneration unit than on technical data.

[5] http://www.ecd.dk

CESI

Case studies were undertaken by 6 students in different companies:

- Student at Teta: study and design different cogeneration plant using biomass and biogas for the city of Reims heating plant.
- Student at Novergie: study and solve the problems found in the boiler of the city of Lagny heating plant
- Student at Dalkia: optimising thermal and cogeneration system for the city of Amiens heating plant.
- Student at ADEME: study and demonstrate the technical and economical feasibility of an ethanol fuel cell in a cogeneration unit for the head office in Angers.
- 2 students at EDF and GDF: study and demonstrate the technical and economical feasibility of different cogeneration units using natural gas to match specific needs.

Most case studies included the full range of analytical steps suggested in the Educogen Work Plan, i.e. a technical analysis of the energy needs of the units examined (energy audit), an economical analysis, an environmental impact assessment, a feasibility study, and the pricing analysis of the current tariffs and energy supplies.

#### 4.2.3.4 Netherlands

The 12 students specialising on cogeneration have studied two theoretical micro-cogeneration options: The fuel cell of Vaillant and the Stirling engine of EnAtEc (ATAG). The possibilities for micro-cogeneration in the Netherlands have been recognised. Also the difficulties are uncovered.

A technical analysis of the energy needs of units examined could not be carried out since these units are still under development. Some reference values were distributed instead. Yet, there was an economical analysis undertaken looking at expected investments and important governmental policies. Also, and environmental impact assessment and a complete feasibility study including pricing analysis of energy tariffs were undertaken. The latter needed to be based on assumptions, as the market is very unpredictable at this moment, especially for students who do not have previous experience in this field. Demand side options were explored through a series of interviews with the manufacturers.

Again, the Educogen Tool was used as a reference book for the case studies.

#### 4.2.3.5 Poland

As the best opportunity for the development of cogeneration technology is seen in the utilization of renewable energy, a number of case studies were underway with students to assess landfill gas utilization for different locations in Poland. 10 bachelor level students were involved. They do an analysis of different, already existing or planned, landfill sites to assess possible methods of landfill gas collection and methods of its utilisation. They also undertake a feasibility study for a cogeneration installation for each of this locations including electric and thermal power demand site calculations. Special emphasis is given to cogeneration

technology that is designed to address the specific of local conditions, i.e. landfill gas supply and potential customers for heat generated from the cogeneration unit.

A technical analysis of the energy needs of units examined is undertaken to help size the unit. Also, a full economic and pricing analysis of different ways of landfill gas utilisation is done and a feasibility study of cogeneration installation is made. The environmental impact of the cogeneration scheme is calculated based on avoided emission of landfill gas and avoided emissions of gases due to avoided energy generation in other sources. Demand side management options were systematically explored, because at landfills there is typically a lack of heat demand to utilise heat generated by a cogeneration unit. In some locations associated investments were therefore explored, e.g. greenhouses, wood dryers etc. to generate heat demand to improve financial justification.

The Educogen Tool next to a range of other materials was used to support the case study work.

## 4.3 Evaluation of the Tool

Task 8 of Educogen, the ‘evaluation of the Tool’, should help improve the content, design and applicability of the Educogen tool, and initiate its dissemination.

### 4.3.1 Methodology

A two-step approach was pursued.

Firstly, an 'on-site evaluation with questionnaire' was to be carried out. In order to gain a first picture of the usefulness, and the strengths and weaknesses of the Educogen Tool – the key product of the project -, an evaluation questionnaire has been developed for four main user groups of the Tool in September 2001. These four groups have been defined as teachers, students, cogeneration professionals and public authorities. A copy of the evaluation questionnaire can be found in Annex 6 of this report. Each project partner was requested to evaluate the Tool together with those persons who have been involved in its creation and application. The questionnaire should be completed for each group that has received the Educogen material and used it.

Secondly, an evaluation workshop in Brussels was scheduled as part of the morning session of the final Educogen meeting in November 2001 in Brussels. The purpose of this workshop was to provide feedback on the Educogen tool and initiate the dissemination phase. Each Educogen partner had the possibility to invite 1 or 2 persons to the workshop, e.g. representatives of the public authorities responsible for education.

### 4.3.2 Results

During the 'on-site evaluation' 15 evaluation questionnaires have been completed and returned:

- 3 questionnaires for students
- 7 questionnaires for teachers
- 4 questionnaires for cogeneration professionals
- 1 questionnaire for public authorities

The number and distribution of questionnaires across the four groups is not large enough to translate the responses into statistical evidence. The relatively low number of responses to the questionnaire is due to the fact that, in many cases, the final version of the Educogen Tool has not been field-tested during at least the cycle of a full academic year. First impressions on the usefulness and educational value of the tool have been gathered during the evaluation phase in late 2001. Yet, viable conclusions could only be drawn from mid-2002, when the teaching modules based on the Educogen Tool are finished, and when exams have taken place. With regard to public authorities, these were difficult to motivate to participate in the questionnaire-based evaluation.

A *quantitative* part of the evaluation questionnaire asked the respondents to rank the Educogen Tool against five criteria. The results of this general assessment, which were confirmed at the evaluation workshop in Brussels, are shown in Table 1. The results indicate that the Tool has been evaluated very favourably in terms of its overall educational value. Also, it scored a very good result in terms of the amount and quality of information provided in it, and its applicability for teaching. Yet, the design and presentation of the Tool could be improved in the opinion of many of its evaluators. As a result of this last point, a second edition of the Tool has been created. This edition features an improved layout, more coherent numbering and headings, and a new chapter on electrical interconnection issues of cogeneration developed by the University of Dundee. This second edition has been uploaded on the Educogen website in late November 2001.

**Table 1: Overall ranking of the Educogen Tool against five criteria**

| | **1 ("Very Good")** | **2** | **3** | **4** | **5 ("Poor")** | **Overall Result** |
|---|---|---|---|---|---|---|
| **Educational value** | 10 | 5 | 0 | 0 | 0 | **1.3** |
| **Quality of Information** | 8 | 7 | 0 | 0 | 0 | **1.5** |
| **Quantity of Information** | 8 | 6 | 0 | 1 | 0 | **1.6** |
| **Applicability for Teacher's courses** | 5 | 10 | 0 | 0 | 0 | **1.7** |
| **Design and Presentation** | 1 | 8 | 6 | 0 | 0 | **2.3** |

The questionnaire also asked a number of *qualitative* questions where the evaluators were asked to express their opinions in relation to the usefulness of the Tool and make statements on its strengths, weaknesses, target groups and future use. The complete replies to these questions are listed in Annex 7 of this report. Complementary to this qualitative part of the questionnaire, the evaluation workshop in Brussels gathered more comments and suggestions that contributed to the evaluation of the Educogen results. The initial idea of this workshop, as proposed in the project proposal, was to invite a number of external evaluators to the workshop to have a fresh look at the results of the project and to come up with independent comments and observations. However, travel expenses of those persons had not been budgeted for and could therefore not be covered from the project budget. This limited the scope of potential participants to a limited circle of persons, mostly from nearby areas (Belgium, Netherlands, and Northeast of France). Despite a number of invitations addressed to experts from these countries, only one person attended in the end the final workshop. Instead, the Educogen partners went together through the first part of the evaluation questionnaires (i.e. for professors/teachers) and presented initial results of the evaluation within their own organisations. The following strengths of the project and its products were identified:

- The Tool is a very complete document which fills a gap on the market. Nothing comparable existed so far. The Educogen partners considered it a valuable reference document and a sort of “Cogeneration Bible”
- The chapters on the different cogeneration technologies, cogeneration economics and cogeneration policies & legislation are good.
- The Tool is well documented.
- The Tool is freely available on the web and has been downloaded very often.

Yet, the following could be improved in the future:

- Chapters on thermodynamics, hydraulics, emission standards, design optimisation should be added. This would, perhaps, make it necessary to rethink the stricture and presentation of the publication on the Internet.
- A chapter with case studies should be added. This can be done by simply adding the case studies undertaken for the Prosmaco project.
- The chapter on micro-cogeneration should be enhanced.

In brief, the results of the qualitative evaluation could be summarised as follows:

- The main outcomes of the Educogen – the Educogen Tool and the Cogeneration Guide – were considered a very useful means to educate and train students at different levels of their university career and other persons on cogeneration. The Tool has been characterised as complete, detailed and extensive reference book.
- The particular strength of the Educogen Tool is seen in its detailed and well-informed coverage of a variety of issues relevant to cogeneration, brought together in one single book.

- Apart from these qualities, the fact that this book has been made available for free on the Internet largely explains its success. Students would need to buy or lend most academic books. In turn, this one is of high quality and for free.
- The question for the weaknesses of the Educogen Tool revealed a dilemma common to all reference books: The length of the Educogen Tool was at the same found to be a disadvantage. Whilst it allows the tool to use as a reference book, going through it requires time and determination. The creation of a summary, or also of an interactive presentation on a CD-ROM, has thus been suggested[6].
- Contrary for calls for simplicity, there were also suggestions to include a number of additional subjects in the book, including thermodynamic analysis, hydraulic integration and regulation, electrical generators and grid interconnections[7], heat demand issues, market data on specific applications, emission standards for applications, and practical, hands on information (case studies and pictures).
- Some comments referred to the way in which the Tool would be updated in the future, particularly in relation to markets, legislation and policies. An updating service could include a mailing list with subscription on the website.
- The Educogen Tools was found suitable not only for academic students, but also technicians, decision makers, politicians, or even customers. Due to its comprehensiveness, the Tool will in most cases be used rather as a reference book, where individual chapters can provide input into specific tasks and lessons. It became clear that the Educogen Tool would find a broad uptake in teaching activities.
- The Educogen webpage was considered a valuable means of distribution for the Educogen book, and possibly as a platform for continued networking.

## 4.4 Dissemination

The dissemination of the Educogen project could be considered one of the most important parts of the project, because it will enable others to benefit from the results of the project. The role of SAVE II projects is to develop and disseminate ways of ensuring rational use of energy. Replicating or multiplying their outcomes implies seeking a ‘return on this investment’, by reaching out to as many potential users as possible.

### 4.4.1 Dissemination Strategy

A long-term dissemination strategy for Educogen has been developed with the aim to reach out beyond the funding period. This dissemination strategy is provided in Annex 8 of this report. It has been developed taking into account the recommendations of the SAVE Dissemination Guide. It defines the key "products" of the Educogen project that are to be disseminated, the most important target groups, and the planned activities including:

[6] It needs to be pointed out, however, that the Cogeneration Guide provides such a summary. It seemed that some evaluators were not aware of the existence of this Guide.

[7] A new chapter on electrical generators and interconnection issues has been created by the University of Dundee and was inserted into the second edition of the Tool in late November 2002

- Creation and continued development of the Educogen webpage as a key mechanism to disseminate the results of the project. This requires regular updates and the addition of new material
- Electronic mass-mailings informing people of the project's results and the Educogen webpage
- Dissemination of information on Educogen to electronic news services and other multipliers, such as ENDS daily, the CORDIS database, regular updates to COGEN Europe members etc.
- Inclusion of information on Educogen into printed news media, for instance *Energy Europe,* Cogeneration and On-Site Power Production (COSPP)
- Dissemination through teaching activities of the Educogen partners
- Presentation of Educogen at conferences, for instance the COGEN Europe annual conference (March 2002)

This dissemination strategy has been discussed at the final meeting of the project partners. At this meeting, the dissemination activities previously suggested in the project proposal have been discussed at length. In the light of the experiences made during the project, the partners decided not to pursue two activities originally envisaged.

Firstly, it became clear that the translation of the Educogen Tool into several other European languages would imply enormous translation costs. Because the emergence of these costs could not be foreseen at the time of writing the proposal, no adequate budget has been included at the beginning. In addition, it was felt that, independently from the cost aspects, the educational value of English versions of the Educogen Tool and the Guide to Cogeneration would be higher. With English becoming increasingly the most important second Community language and an indispensable skill for academics, added value could be gained from providing the Educogen publications in this language only.

Secondly, the idea to release of a "booklet and/or CD-ROM containing a brief history of the project, the best case studies, and outline of the Educogen package" was changed to some extent. When it became clear that the Educogen webpage was the most attractive and efficient dissemination path of the project, it was decided that it should contain all Educogen outcomes created, and that dissemination activities should mostly concentrate on the marketing of this page and the products it offers. The Internet is increasingly becoming a universally available source of information, and the high number of visitors of the Educogen website confirmed that most efforts should be dedicated to using this mechanism rather than to dissipate energy into duplicating these products (e.g. condensing them into another booklet) and trying to distribute them on a different dissemination path (sending CD-ROMs with exactly the same content that is available on the Internet).

### 4.4.2 Teaching Activities

All Educogen partners used the Educogen Tool and the Guide to Cogeneration into their teaching programmes. This is explained in more detail in Chapter 4.2 of this report. It is difficult to indicate the numbers of students reached through these activities. From the implementation reports obtained it could be estimated that more than 1000 students have

obtained copies of the Tool or have been requested to use it. Another 2500 students at least have been given the opportunity to obtain the tool from libraries, or have been made aware of the Educogen webpage.

### 4.4.3 Educogen Conferences

On the occasion of two of the regular meetings of the Educogen project team, two 1-day conferences were organised that addressed the wider public. These conferences involved all project partners, and as well as other stakeholders of the energy sector in the respective country. The conference programmes are provided in Annex 5 to this report.

The first of these conferences was celebrated in Douai, on 29 November 2000. it gathered students of the second, third and fourth years of *Ecole des mines de Douai*, and students from ICAM and CESI. The presentations were performed by Educogen partners and also by two representatives from industries directly linked with energy and cogeneration, ELYO and GDF. This conference was open to the broad public and an information campaign was made in order to gather the maximum number of people. An article was written for the school newspaper (1000 readers, see picture), the conference program was published on the school website, and an email was sent to about 350 human resources managers from industry.

The second conference occurred on 24 April 2001 in Dundee, Scotland. On the occasion of a regular project meeting a wider Educogen conference was organised with the aim to disseminate information on the project and provide a forum for debate on its contents.

### 4.4.4 Educogen Website

When COGEN Europe published in September 2001 their new webpage on the Internet, a specific site on the Educogen project was added as part of the pre-dissemination activities of the Educogen project[8]. This site lists the project partners with links to their homepages and to their sites relating to Educogen, the project duration, a contact person, a brief outline of the project, and all products of the Educogen project in form of downloadable files.

The purpose of the Educogen website is to provide information on the project to a wider audience, and to be a cost-efficient means of distributing publications created during the project, notably

- the Educogen Tool (second enhanced version from December 2001, including the new chapter on electrical interconnection issues)
- the Cogeneration Guide from March 2001
- 'La Cogénération'; a French adaptation of the Educogen Tool
- Power Point Presentations in English and French on the project.

[8] http://www.cogen.org/projects/educogen.htm


COGEN Europe -
The European Association for the
Promotion of Cogeneration
EDUCOGEN
The European Education Tool on Energy-Efficiency
through the Use of Cogeneration (Combined Heat and Power)
Partners:
Duration:
January 2000 - February 2002


Project Webpages:
Webpages on EDUCOGEN activities of the project partners:
University of Dundee:
Ecole d'Ingénieurs Mines de Douai:
Formation à la cogénération
Université Catholique de Louvain, Unité de thermodynamique (TECIM):
Contact:
Peter Loffler
Research Executive
COGEN Europe
Description:
EDUCOGEN: 'Cogeneration goes to European universities and engineering schools'
Phase 1: Inception, Kick Off
Phase 2: Analysis and creation of the tool (Identification of training needs from the energy industry and training opportunities from the education community / Creation of a framework for courses / Installation of micro CHP units in each university
Phase 3: Pilot implementation of the tool (Theoretical sessions on the concept of cogeneration and the installed unit / Practical experiments around the installed unit / Analysis of case studies
Phase 4: Evaluation of the tool (Evaluation work conducted by a workshop)


**Figure 7: Screenshots of the Educogen webpage**

The page serves also, as envisaged in the project proposal, as a platform specifically dedicated to the academic world, where additional materials and publications are offered. To date, the following studies are provided for download:

- "Control Strategy Evaluation & Market Potential of Inverter Driven Micro-Combined Heat and Power Units". MSc Thesis at the University of Dundee, Department of Electronic Engineering and Physics by Pantelis Tsakiris (2001)
- "Analyse de Systèmes de micro-cogénération" MSc Thesis at the Université Catholique de Louvain, Faculté des Sciences Appliquées, Département de mécanique, Unité TERM by Ismaël Daoud and Nicolas Pierreux (2000)
- Micro-WKK: meer dan koppeling van Warmte en Kracht alleen. Universiteit Utrecht, Natuurwetenschap & Innovatiemanagement, Innovatieproject 3. (2001, 326 KB)
- Micro W/K in huishoudens. Universiteit Utrecht, Natuurwetenschap & Innovatiemanagement, Innovatieproject 3 (2001) Report and Annex
- Cogeneration Guide "La petite cogénération. Pourquoi? Pour qui?" published by Cogensud (in English and French)

Most of these additional materials have been provided by Educogen partners, who want to continue co-operating after the project's funding period and providing new publications for the Educogen website.

The Educogen webpage was marketed extensively and has taken a central role in the dissemination of the project. Some of the project partners have created links on their webpages to the Educogen page, thereby increasing the use of this page, and the number of downloads from it. Personal recommendations were equally made to students during courses and seminars, with the result that many students from these universities were visiting the page from their university web servers. This can be proved by the statistics of the COGEN Europe webpage. Most importantly perhaps, two electronic mailings have been sent out to roughly 1300 members of the target group (see chapter 4.4.5)

As a result of this marketing strategy, the Educogen website was a big success and has become a key tool for the dissemination phase of the project. Between late September 2001 and end February 2002, it had 1410 visits, far more than any other project site on the COGEN Europe webpage. During that period, 6463 copies of all publications offered on the site have been downloaded from that page, including more than 2000 copies each of the Educogen Tool and the Cogeneration Guide. Figure 8 shows how many copies of each publication have been downloaded. Generally, the use of the Educogen webpage, and particularly the number of downloads of key publications developed through the project – the Educogen Tool and the Cogeneration Guide – have been increasing since the website is on-line (see Figure 9).

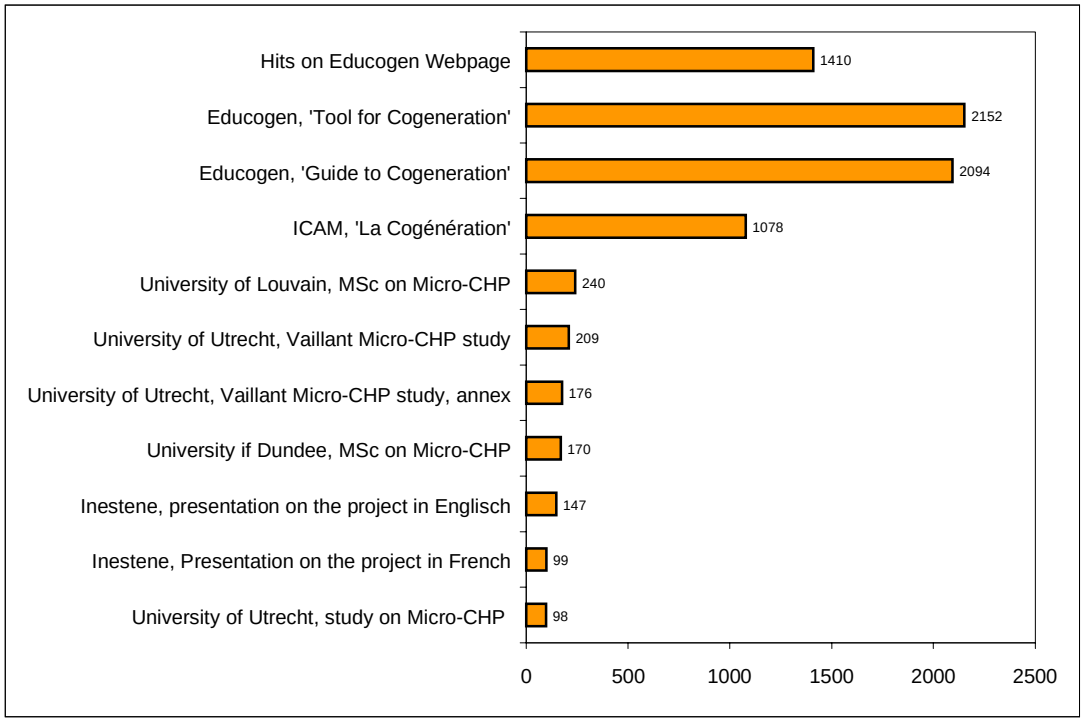


**Figure 8: Total number of hits/downloads from the Educogen Website between October 2001 and February 2002**

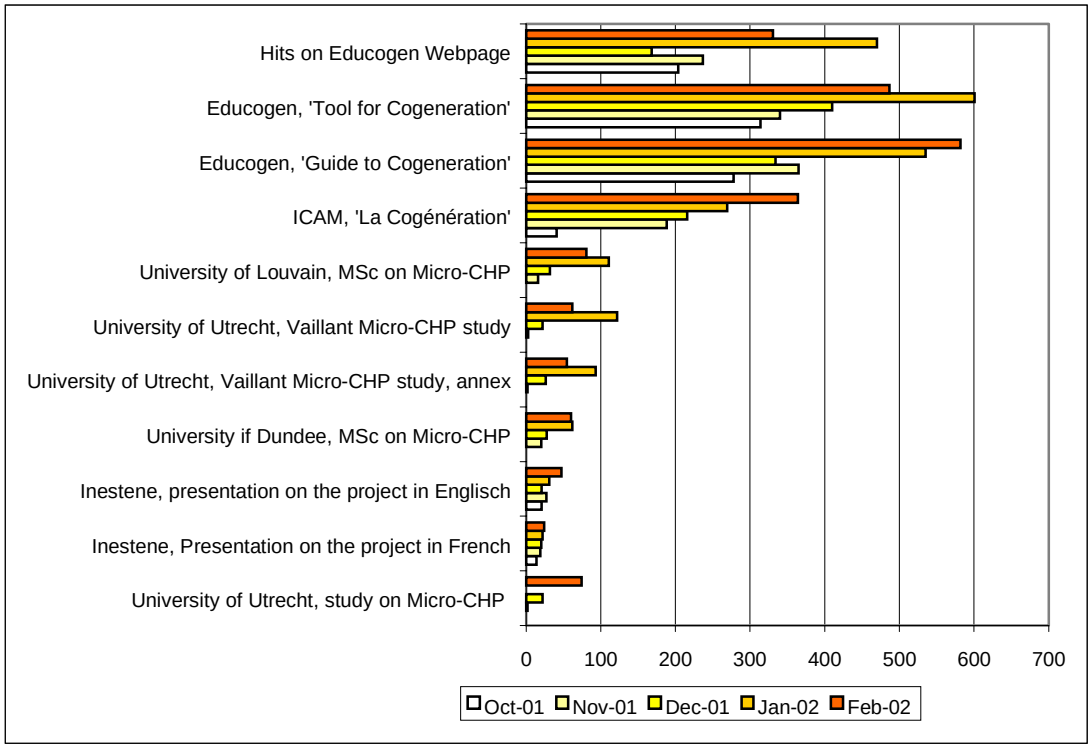


**Figure 9: Number of hits/downloads from the Educogen Website between October 2001 and February 2002 by month**

### 4.4.5 Electronic Mailings

The Ecole des Mines de Douai has sent, on the occasion of their Educogen conference in 2000, an email to about 350 human resources managers from industry, informing them of the project and the conference.

The Hellenic CHP Association informed its more than 100 members of the Educogen Tool.

Two electronic mailings raising awareness of the Educogen project and website have been sent out in early 2002. The first was sent to a mailing list compiled with the help of all Educogen partners according to the specifications from the dissemination strategy. It listed 305 key persons, including national cogeneration associations and other professional associations, university staff, companies, networks and information services. These persons received a short cover note making them aware of the Educogen outcomes and the webpage, together with a flyer on the project in pdf format (see Figure 10). The second mailing was distributed to the mailing list of the International Cogeneration Alliance (ICA), which contains more than 800 addresses. A third mailing addressed the 170 members of COGEN Europe, bringing the total number of recipients of the mailing to almost 1500. The mailings resulted in a considerable rise in the visits to the Educogen webpage and the number of downloads from this page.

Apart from leading directly to more use of the Educogen webpage, the mailings also had a secondary effect. Some of the recipients distributed, in turn, information on Educogen using their own distribution channels. For instance

- Energy Centre Denmark made a notice on the project in their E-newsletter, which is circulated to 250 clients in the Danish energy sector.
- An article will be published in the March 2002 edition of the German energiewerkbrief/KWK-Forum
- An article in the Newsletter of COGEN Vlaanderen has been published in November 2001

Also, a number of links to the Educogen webpage have been created by February 2002 on other websites including those of COGEN Vlaanderen (Belgium), UCL Unité Term (Belgium), the US cogeneration Association (USA), Xi'an Jiaotong University (China), Sustainable Minnesota Web Site (USA), and Baltenergy (Estonia).


**Figure 10: Flyer on the Educogen Project used for mailings**

### 4.4.6 Presentation of Educogen at Conferences

The Educogen project was presented to the delegates of COGEN Europe's Annual Conference in March 2002.

### 4.4.7 Summary

The following figures summarise the dissemination activities undertaken to promote Educogen:

- 1000 students have obtained copies of the Tool, and at least 2500 students plus probably several thousand other contacts have been reached indirectly.
- Approximately 1700 contacts received emails informing them of the Educogen project and its outcomes.

- 1410 visits to the Educogen webpage and 6463 files downloaded from this page by February 2002 have been registered.
- 2 Educogen conferences have been organised.
- Probably more than 3000 persons obtained copies of the Educogen Tool.
- By March 2002, links to the Educogen website have been created on 13 other sites.

## 4.5 Outlook

### 4.5.1 Continuation of the network of Educogen partners

The Educogen project established a network between the project partners, but also reaching out to other educational and training organisations across Europe. The final project meeting showed that all Educogen partners have an interest to

- maintain contact with a view to continue exchanging their experiences and knowledge etc. For this purpose, COGEN Europe maintains a mailing list of all project partners.
- try to enlarge the network by adding other actors to the mailing list.
- initiate regular exchange of students between their respective organisations.
- undertake study trips to cogeneration units operated by other partners.

### 4.5.2 Continuation of Dissemination

The Educogen webpage has become a central tool for awareness rising, communication and dissemination of the Educogen Project. Its use for dissemination will therefore be continued.

The page is hosted on COGEN Europe's webpage, which is updated regularly. It is therefore guaranteed that the Educogen page will also be kept up to date and developed on a regular basis. The latest additions to the page include a number of studies and research reports on cogeneration which have been downloaded many times. The final publishable project report will equally be made available on the project webpage.

At their last meeting in Brussels, the project partners agreed that they would continue to submit studies and research reports which would be offered on this page.

COGEN Europe will continue to market the Educogen webpage. Notification of new additions to the page will be sent to their members, to the Educogen mailing list, and from time to time also to the ICA mailing list, thereby reaching far more than 1000 recipients.

## 4.6 Lessons learnt and Conclusions

The experiences made during the Educogen show the following:

- There is an enormous potential to improve education and training on cogeneration in Europe both in terms of quantity and quality.
- International networking and exchange of experiences between different education and training organisations can greatly enhance the quantity and quality of training on cogeneration. It gives added value to existing individual efforts by bringing together knowledge, skills and experiences.
- Education and training on cogeneration has different aims. A comprehensive educational tool therefore needs to be flexible. If the objective is to prepare engineers for their future jobs in industry, the training can mainly focus on technological issues. If education aims to promote cogeneration, a different target group needs to be addressed, and issues such as economies, environmental impacts and institutional matters become more important.
- The Educogen Tool was a first step towards closing a gap in this respect. It effectively provided the first European reference books on cogeneration which address technological, economical, environmental, and institutional aspects of cogeneration.
- Materials such as the Educogen Tool and the Guide to Cogeneration can contribute to the achievement of the European cogeneration target of 18% electricity from cogeneration in 2010. They provide engineers with the necessary skills and technical know-how. At the same time, they facilitate a better understanding of the environmental ad economic benefits of cogeneration, and the political and institutional mechanisms that bring about growth in this sector.
- Community policies and programmes should continue to support projects such as Educogen, because they enhance education and training on cogeneration. This in turn is beneficial for Community energy policy objectives, such as competitiveness, environmental protection, energy efficiency and security of supply.

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**List of Abbreviations**

| | |
|---|---|
| ATEE | Association Technique Energie et Environnement |
| CHP | Combined Heat and Power |
| DTI | Danish Technological Institute |
| EDF | Eléctricité de France |
| GDF | Gaz de France |
| ICAM | Institut Catholique d'Arts et Métiers |
| $MW_e$ | Megawatt (electrical) |
| NTUA | National Technical University of Athens |
| UCL | Université Catholique de Louvain |
| $kW_e$ | Megawatt (thermal) |