umweltbundesamt

ENERGY EFFICIENCY IN IPPC INSTALLATIONS

European Conference

Vienna, 21st and 22nd of October 2004

CONFERENCE PAPERS
CP-036

Vienna, 2004

Project management

Ilona Szednyj
Karl Jamek
Ilse Schindler
Anikó Rechberger

We would like to thank all authors for their effort in preparing their written contribution.

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PREFACE

The topic of energy efficiency is more and more important in the current political and environmental debate. In this connection, the Umweltbundesamt is glad to present hereafter the papers of the European conference "Energy efficiency in IPPC installations" as rich input to this ongoing debate.

Energy efficiency is central to the EU directive concerning Integrated Pollution Prevention and Control, the so-called IPPC directive. Article 3 of the IPPC Directive states that energy shall be used efficiently. Therefore, permitting authorities have to consider energy efficiency when permitting an industrial installation. Additionally, regulating authorities have to consider energy efficiency when implementing the Directives on Combined Heat and Power and Emission Trading.

The efficient use of energy contributes to sustainable development and leads to an improvement of supply security. Since the efficient use of energy also reduces emissions related to thermal processes, especially CO_2, an increase in energy efficiency is one of the key priorities in climate protection strategies. Finally, energy efficiency offers a widing perspective of environment-economic win-win-situations due to ever increasing oil and electricity prices.

The different contributions in the conference proceedings approach the topic of energy efficiency from a variety of perspectives: political and legal framework (IPPC, emission trading, CHP directive, energy taxes, voluntary measures), sector-specific energy efficiency measures, cross-cutting considerations on energy efficiency, management as well as auditing & benchmarking of energy efficiency.

The proceedings are full of innovative examples for energy efficiency measures in IPPC installations from all over Europe. Moreover, a comprehensive input to the forthcoming discussion process on energy efficiency in IPPC installations is provided.

It is the intention of the organisers that the conference encourages the dialogue between all principal players in the field of energy efficiency. In essence, we hope that this conference may serve as discussion platform to support the European information exchange on energy efficiency in IPPC installations.

Georg Rebernig
Managing Director

PROGRAMME

Thursday, 21 October

09:00 – 12:00 Plenary opening session,
chair: Karl Kienzl (A), Umweltbundesamt

Opening of and introduction to the conference, *Georg Rebernig (A), Umweltbundesamt & Waltraud Petek (A), BMLFUW*

Key Drivers for Industrial Performance in EU 25, *Herbert Aichinger (A), European Commission*

Interaction of different legal requirements, *Wolfgang Brenner (A), WKÖ/BSI*

Role of energy efficiency in the BAT Reference Documents, *Don Litten (UK), European IPPC Bureau*

Authorities' role in the assessment of energy efficiency, *Marianne Lindström (FL), Finnish Environment Institute SYKE*

Role of voluntary measures with regard to efficient energy use, *Franzjosef Schafhausen (D), Bundesumweltministerium*

IPPC vs. Emission Trading, *Lesley James (UK), Friends of the Earth*

12:00 – 13:30 Lunch break

13:30 – 15:45 Plenary session: Producing more with less:
Efficiency in Power Generation, *chair: Herbert Aichinger (A), European Comission*

Energy-Efficiency in Permitting – a challenge to the licensor, *Jerry Roukens (NL), Consulting and business development*

Modern Combined Cycle Power Plants – Improvement of a high efficient and clean technology, *Olaf Kreyenberg, H. Schütz & Heimo Friede (D), Siemens*

CO_2 reduction targets call for applying BAT; a new 800 MW combined cycle power plant south of Graz, *Josef Tauschitz & Martin Hochfellner (A), Verbund ATP*

Efficient Energy Supply (Electricity and District Heat) for the city of Linz, *Johann Gimmelsberger (A), Linz Strom GmbH*

"The flameless operation mode": An efficient combustion device leading also to very low NOx emission levels, *Francois Delacroix (F), ADEME*

Energy Efficiency in power plants, *Frans Van Aart (NL), KEMA*

15:45 – 16:15 Coffee break

16:15 – 18:00 Parallel sessions: Innovative energy efficiency examples of different industrial sectors

Energy efficiency in pulp & paper and sugar industry, *chair: Karl Kienzl (A), Umweltbundesamt*

Optimisation of Steam and Condensate Systems of Paper Machines, *Gerald Bachmann (A), Allplan GmbH*

Energy saving measures on the site of M-real Hallein AG, *Erich Feldbaumer (A), M-real Hallein AG*

Innovative examples of energy efficiency in the German sugar industry – Drying process for beet chips, *Christian Voß (D), Südzucker AG & Joachim Wieting (D), UBA Berlin*

Reduction of energy consumption by the Austrian sugar factories (1990–2002), *Josef Merkl (A), Agrana*

Energy efficiency in the cement, metal and petrochemical industry *chair: Gertraud Wollansky (A), BMLFUW*

Co-processing of waste and energy efficiency by cement plants, *Richard Bolwerk (D), Council Government Münster*

From 167 GWh to 72 GWh – Ventilation Demand in LKAB Iron Ore Mine Malmberget, *Peder Nensen (S) & Anders Lundkvist (S), LKAB*

Process Measures implemented into an IPPC Nodular Iron Large Series Automotive Foundry to increase energy efficiency, *Silvia Ribeiro (P), Associacao Portuguea de Fundicao*

Energy Efficiency and Innovative Emerging Technologies for Olefin Production, *Tao Ren (NL), Utrecht University*

Friday, 22 October

09:00 – 10:30 Plenary session: Management and monitoring of energy efficiency*, chair: Waltraud Petek (A), BMLFUW*

Energy Auditing for IPPC facilities in Ireland, *Michael Owens (IRL), EPA*

Energy Management as a European wide standard for continuous improvement, *Rainer Stifter (A), Energon GmbH*

Integrated Resource and Waste Management, some examples and challenges to the Swedish Resource Sector, *Husamuddin Ahmadzai (S), Swedish EPA*

Combining IPPC and Emission Trading: energy efficiency and CO_2 reduction potentials in the Austrian Paper Industry, *Otto Starzer (A), EVA*

10:30 – 11:00 Coffee break

11:00 – 12:15 Plenary session: Cross-cutting energy efficiency measures, *chair: Fritz Unterpertinger (A), EVA*

Analysis of Energy Efficiency Measures in Latvia. Potential of Emission Trading, *Marika Blumberga (LV), TU Riga*

The contribution of electro-technologies to energy efficiency, *Paul Baudry (F), Union of the Electric Industry*

Energy Efficiency Programs in Industrial Companies, *Andreas Kolleger (A), Allplan GmbH*

12:15 – 13:30 Lunch break

13:30 – 14:20 Plenary session: Assessment of energy reduction potential in industry, *chair: Don Litten (UK), EIPPC*

The Energy Efficiency Benchmarking System and BAT, *Hubert van den Bergh (BE), Verification Bureau*

Potential BATs in Energy Efficiency and related legal instruments in the Czech republic, *Vladimira Henelova (CZ) & Monika Prybilova (CZ), ENVIROS and Petr Honskus (CZ), SPG Group*

14:20 – 14:45 Coffee break

14:45 – 16:15 Plenary final discussion, *chair: Don Litten (UK), EIPPC*
Energy Efficiency – a Challenge for Sustainable Development: Chances and Risks for Implementation

Herbert Aichinger (European Commission), Lesley James (Friends of the earth), Sebastian Spaun (VÖZ), Patrick Arbeau (Solvay, BE), Hubert van den Bergh (Verification Bureau), Fritz Unterpertinger (EVA), Jerry Roukens (Consultant), Hans Zeinhofer (Eurelectric), Wolfgang Brenner (WKÖ/BSI)

– end of the conference

Plenary opening session

KEY DRIVERS FOR INDUSTRIAL PERFORMANCE

Herbert Aichinger
European Commission
DG Environment
Directorate G Sustainable development and Integration
Unit Industry

Key drivers for industrial performance

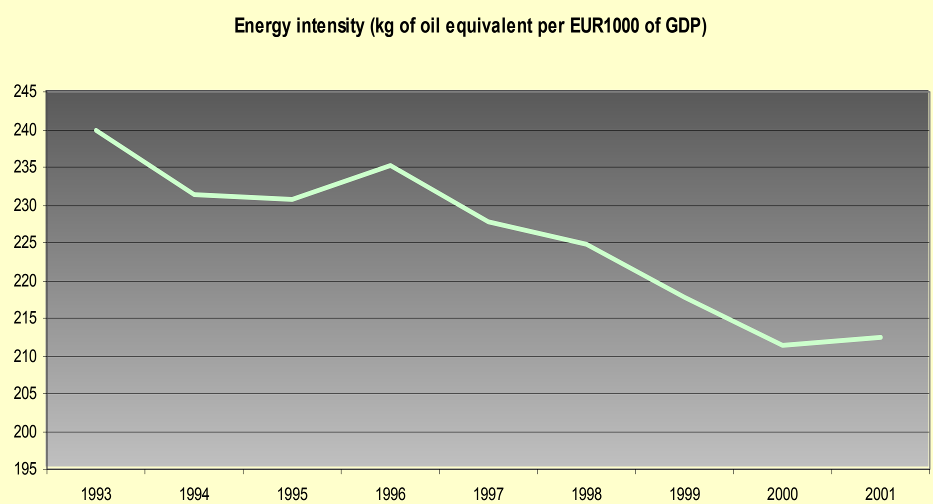
Herbert Aichinger
European Commission
DG Environment
Directorate G Sustainable development and Integration
Unit Industry

Putting energy efficiency into a wider context

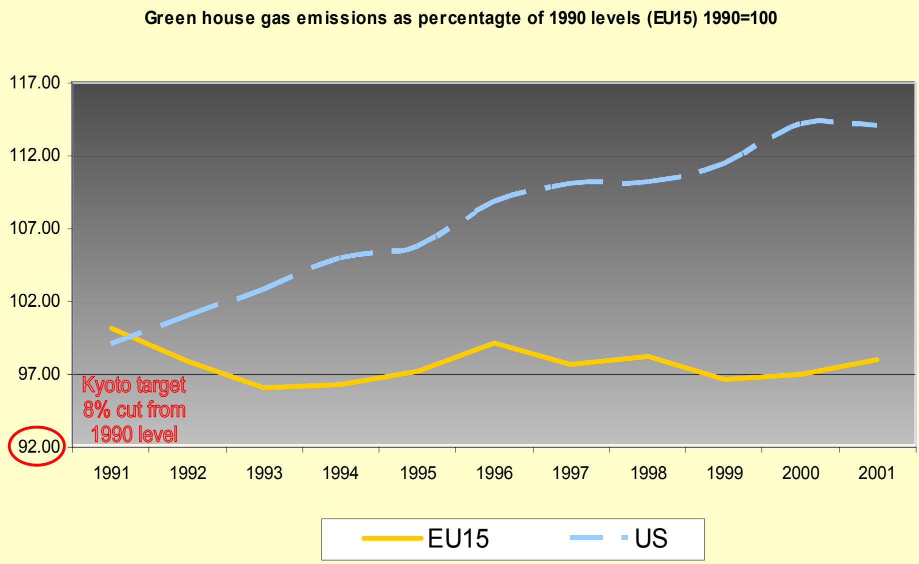
- How are we doing?
- What is happening outside the EU?
- What are the internal EU drivers for greater efficiency?
- What solutions can the European Commission deliver?

Identifying problems…

We are doing fine…



…or at least better than others…

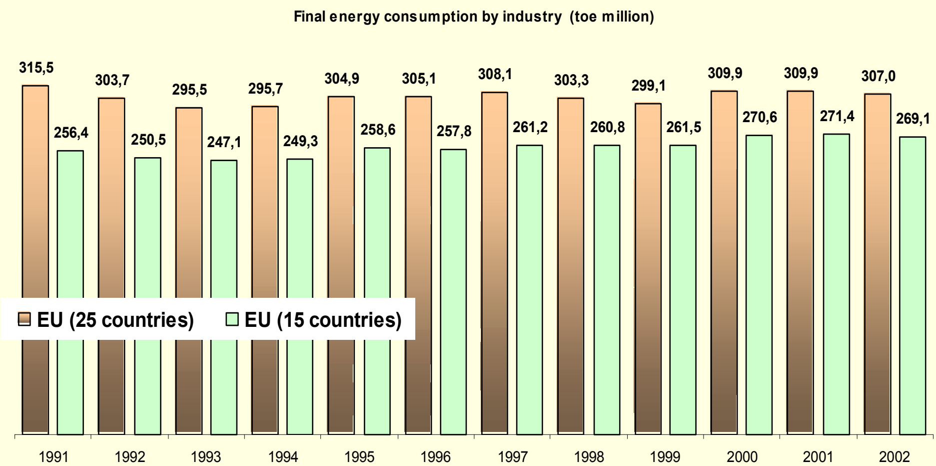


…so why should we care about greater energy efficiency?

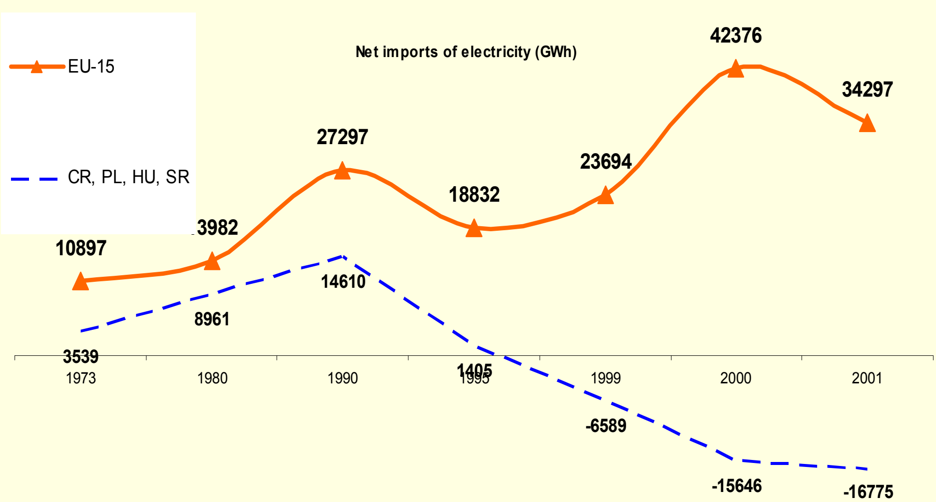
Worrying trends:

- Growing dependence on energy imports
- Growing demand from developing economies
- Remedying the greenhouse effect

Because absolute energy use is fairly stable…



…while our dependence on energy imports is growing.



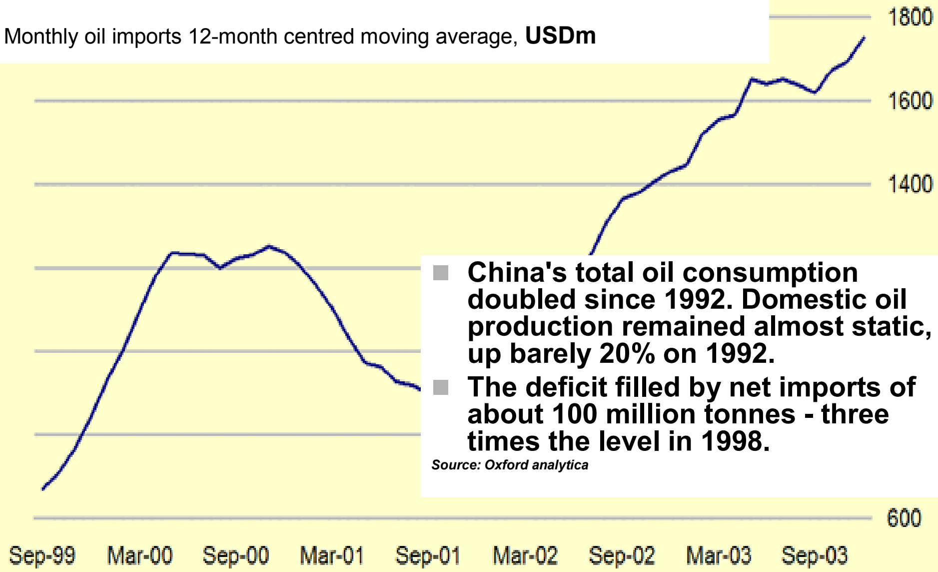
Growing dependence

EU Energy Outlook to 2020:

- Total primary energy consumption ☝ +1% pa until 2010 and ☝ +0.4% pa until 2020
- Energy intensity ☟ 1.5% pa towards 2020
- 2/3 of overall EU energy use imported by 2020 (<1/2 in 1995), gas gaining highest growth
- EU gas importers from Russia to face competition from China

Asia's growing appetite

Monthly oil imports 12-month centred moving average, **USDm**



- **China's total oil consumption doubled since 1992. Domestic oil production remained almost static, up barely 20% on 1992.**
- **The deficit filled by net imports of about 100 million tonnes - three times the level in 1998.**

Source: Oxford analytica

Source: State Statistics Bureau via Bloomberg

The new member states

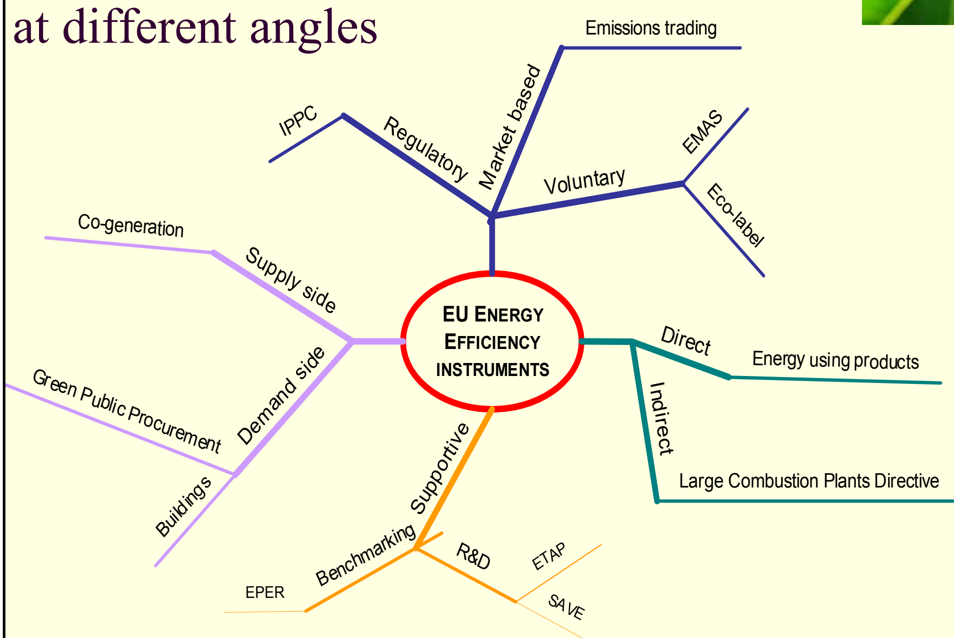
- Average GDP growth in 10 Acceding Countries 1995-2002 = 3,6% per annum, EU15 only 2,2%
- Labour productivity growth in 10 Acceding Countries (1995-2000) = 3,6 % p.a., EU15 only 1%
- Influx of Cohesion and Structural Funds: €8,9 billion in 2004-2006 (of €21.7 billion to be allocated)
- Investment needs in environment field ca €100 billion euro

The new member states – major industrial sectors

Industry share in total manufacturing, %	10 Accession Countries	15 Current Member States
Food products, beverages and tobacco	19,1	13,7
Basic metals and fabricated metal products	12,5	11,1
Electrical and optical equipment	10,2	12
Transport equipment	11,3	13,6

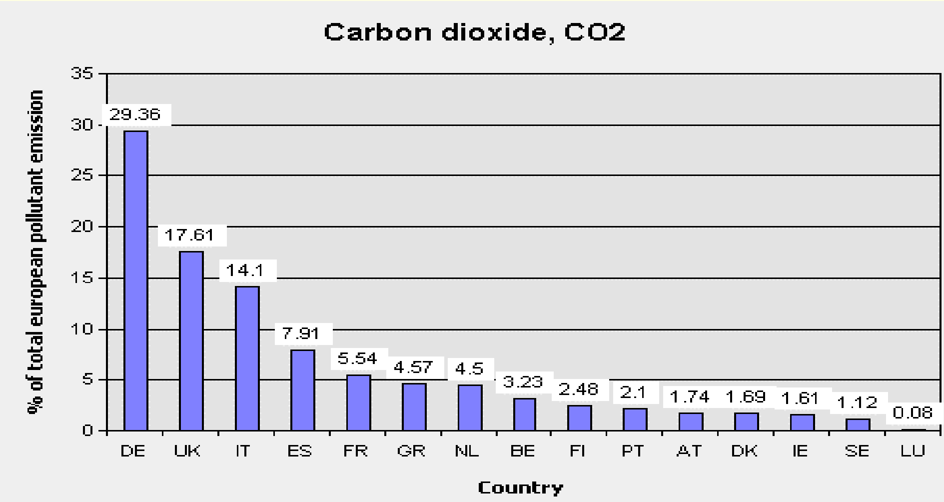
Delivering solutions…

EU instruments for energy efficiency at different angles



EPER: basis for benchmarking

- Principal emissions (50 pollutants) and IPPC sources responsible
- Published every 3 years: first time February 2004
- http://www.eper.cec.eu.int



Environmental Technologies Action Program: boosting competitiveness and environmental protection

- Increase and focus the effort in R&D programmes
- Technology platforms (Hydrogen, Water, Solar)
- Networks for technology testing
- Performance targets for key products and processes
- Financial instruments with appropriate risk sharing
- Review of State aid guidelines
- Review of Environmentally harmful subsidies
- Green public procurement
- Rising business and consumer awareness
- Provide targeted training
- Responsible investments in developing countries

Voluntary Measures: EMAS

- Energy efficiency guidelines for small and medium sized enterprises:
  - Heating, lighting, ventilation, electric motors
  - Goal definition, data collection, input-output analysis, sampling of indicators and definition of measures
  - To be available by the end of 2004

IPPC BREF on energy efficiency

- Considerable potential (all in all 12-14%) for cost-effective energy savings in IPPC plants
- IMPEL study (May 2000): there is little experience so far with energy efficiency provisions in integrated permits
- The Finnish Environment Institute has proposed a new IMPEL study
- The work on BREF will start 2005

Getting demand right – Green public procurement

- Buying green! – Handbook on environmental public procurement
- Energy efficiency as environmental factor to be put in technical specifications
- Products and services

- http://europa.eu.int/comm/environment/gpp/guidelines.htm#handbook

COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 18.8.2004
SEC(2004) 1050

COMMISSION STAFF WORKING DOCUMENT

Buying green!

A handbook on environmental public procurement

Community support for innovation

Field	Vertical Key Actions	150-160 Mio €
SAVE	51-55 Mio €	
ALTENER	59-63 Mio €	
STEER	24-26 Mio €	
COOPENER	17,4 Mio €	
Field	**Horizontal Key Actions**	**36-45 Mio €**
ALL	36-45 Mio €	

Concluding remarks

- Energy demand will rise – internally and externally
- Increasing energy efficiency might be crucial for industrial competitiveness
- Rise in energy efficiency will depend on price signals and technological breakthrough
- The key guidance document will be BREF on energy efficiency
- Need to integrate energy-efficiency in other sectors (households, transport)

Plenary opening session

HORIZONTAL BREF ON GENERIC ENERGY EFFICIENT TECHNIQUES - INTERACTION OF DIFFERENT LEGAL REQUIREMENTS

Wolfgang Brenner
Austrian Federal Economic Chamber; Division Industry
Wiedner Hauptstraße 63; 1045 Wien
Tel: 05 90900 / 3423 Mail: Wolfgang.Brenner@wko.at

HORIZONTAL BREF ON GENERIC ENERGY EFFICIENT TECHNIQUES - INTERACTION OF DIFFERENT LEGAL REQUIREMENTS

Wolfgang Brenner; *Austrian Federal Economic Chamber; Division Industry*

The Industry does welcome any attempt to increase the efficient use of energy. The efficient use of energy is, besides the efficient production, a major strategy to face the problem of a "possible energy crisis", namely the increasing prices of energy.

But the big question is – Do we need a new horizontal BREF, a new difficult "legal document"?

The Industry feels, that it would be better to insert necessary techniques in the sectoral Brefs during their revisions.

Let me discuss this thoughts with the following points:

IPPC Directive

The following regulations of the directive should be considered while working on the BREF.

The preamble:
"*…The best available techniques, without prescribing the use of one specific technique or technology and taking into consideration the technical characteristic of the installation concerned, its geographical location and local environmental conditions.*"

The IPPC directive deals with energy efficiency in a very short way.

Article 3 IPPC:
"General Principles governing the basic obligations of the operator :
…(d) energy is used efficiently …"

Article 6 IPPC:
"The competent authority has to ensure, that the permit includes a description of …. the energy used in or generated by the installation,"

This rules do not enforce any horizontal BREF.

Sectoral approach

It is interesting for the operators of IPPC plants how the horizontal BREF can work. Every branch has typical plants with typical requirements.

- Energy intensive branches (f.e.: pulp and paper) are using energy in the most efficient way today. But not every paper plant can use f.e. CHP technologies on the site. Local environmental conditions may not allow this.
  → How will the BREF handle this cases?
  → Will the BREF be applicable additionally the Bref Pulp and Paper?
- Non energy intensive branches (f.e. metal working industries) do not use energy that efficient today like pulp and paper industry. And this is not needed from the economic point of view.
  → Will there be any concern on the "economically needed"?
- The BREF could cover techniques common to more than one sector.
  → What will happen, when the sectoral BREF is reviewed? Is there a review of the BREF compulsory?

This questions could lead to the answer, that the horizontal BREF could be replaced by the already large number of sectoral Brefs. Why not amend and supplement this sectoral Brefs with information about the appropriate "efficient energy use"?

Scope of the BREF

If there is a BREF designed, the BREF should define its scope exactly. The IEF IPPC bureau should await the decision of the legal service of the EU-Commission before starting the work.

<u>IPP and EUP</u>
A major problem in discussing the scope of the BREF is the possible overlap with the EUP directive (energy using products). The EUP directive will state rules for the eco design of energy using products. *"This Directive establishes a framework for the integration of environmental aspects in product design and development to ensure the free movement of energy-using products within the internal market."*
The energy consumption during use is on of the important eco requirement for the design of the energy using products.
EUP will cover:

- Electric motors and drives
- Generators
- Pumps
- Refrigeration ……….

The insulation etc. of buildings are covered by other directives.

The IPPC Directive prohibits the prescribing of a certain technique (the use of a certain product) and the freedom of movement of goods does prohibit the BREF to state any obstacles for goods in the common market (esp. those having the CE sign).

<u>Freedom of movement of goods and WTO</u>
The BREF faces the absolute border of the "freedom of the movement of goods" in the EU´s common market. Goods (like electrical machines, pumps etc.) once legally entered the common market must not be hindered in the movement by customs or obstacles like customs. Would the BREF establish any of this obstacles, which are not covered by article 6 of the Treaty of the European Union, the BREF must not be applied by the authority.

A similar problem would cause the BREF by stating any obstacles for legally imported goods from member states of the WTO.

Energy Efficiency and EU-Emission Trading

The "production" of the greenhouse gases is often a problem of energy production. Efficient production, efficient transport and efficient use of energy is important to reduce greenhouse gases.
The BREF should handle the different scopes of the Emission Trading and the IPPC directive.
Besides this problem, techniques on efficient energy use in non Emission Trading sectors could be useful.

CHP (Combined Heat and Power Production)

The CHP Directive is the main driver for the discussion in Austria to support the use of CHP in industrial sectors.
A horizontal BREF is not the most efficient way to encourage the industry to use CHP technologies in the plants:

- CHPs are producing electric current and heat on the site. But it is not allowed to "produce" dust, or ozone substances on every site. (Vienna region, Graz region).
- CHPs will become more and more attractive facing the increasing energy prices.

Plenary opening session

ROLE OF ENERGY EFFICIENCY IN THE BAT REFERENCE DOCUMENTS

Don Litten,
Head of the European IPPC Bureau
Institute for Prospective Technological Studies (IPTS)
Directorate General - Joint Research Centre (JRC),
European Commission
Edificio Expo, Isla de la Cartuja, Sevilla, E-41092 Spain
e.mail : JRC-IPTS-EIPPCB@cec.eu.int; http://eippcb.jrc.es

ROLE OF ENERGY EFFICIENCY IN THE BAT REFERENCE DOCUMENTS

Don Litten, *Head of the European IPPC Bureau Institute for Prospective Technological Studies (IPTS) Directorate General - Joint Research Centre (JRC), European Commission*

Abstract

Council Directive 96/61/EC concerning integrated pollution prevention and control (IPPC) requires Member States to introduce a system of operating permits for certain categories of industrial activities (Annex 1 to the Directive). The Directive requires Member States to introduce this permit system no later than October 1999 for new and substantially changed installations and no later than 8 years later by October 2007 for all existing installations. The permit shall cover core Annex 1 activities and other directly associated activities on the site in order to consider all the important activities in an integrated way. The permit shall include conditions and emission limit values based on “best available techniques” (BAT) but taking into account local considerations such as the technical characteristics of the installation and any special needs of the local environment. The Directive defines BAT to be best for reducing impact on the environment as a whole and the Directive explicitly seeks to ensure that energy is used efficiently. Article 16(2) provides that there shall be an information exchange between Member States and the industries concerned on “best available techniques”, associated monitoring and developments in them.

1 The IPPC Directive

The Directive 96/61/EC concerning integrated pollution prevention and control (IPPC) requires Member States to introduce a system of operating permits for certain categories of industrial activities. The core activities covered by IPPC are given in Annex 1 to the Directive. The Directive is transposed into national legislation and Member States can apply their national IPPC legislation to a wider scope of installations than the minimum required by the Directive.

Member States had to introduce this permit system no later than October 1999 for new and substantially changed installations and no later than 8 years later by October 2007 for all existing installations. Permits shall cover core Annex 1 activities and other directly associated activities on the site in order to consider all the important activities in an integrated way. The permit shall include conditions and emission limit values based on “best available techniques” (BAT) but taking into account local considerations such as the technical characteristics of the installation and any special needs of the local environment (Article 9(4)). The IPPC Directive has so far been amended by Directives 2003/35/EC, 2003/87/EC and Regulation (EC) No 1882/2003.

2 Best Available Techniques (BAT)

Article 2(11) of the Directive defines BAT.

- 'best available techniques` shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:

- 'techniques` shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned,

- 'available` techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,

- 'best` shall mean most effective in achieving a high general level of protection of the environment as a whole.

In addition to the Directive definition of BAT, Article 3 requires that IPPC installations are operated in such a way that energy is used efficiently.

3 The Sevilla process and BAT reference documents (BREFs)

Article 16(2) requires the Commission to organise an information exchange on best available techniques, associated monitoring and developments in them. It does not refer to setting emission limit values. Article 9(4) explicitly states that BAT is one of the inputs to determine permit conditions and Recital 18 of the Directive clearly leaves it for Member States to determine how to implement Article 9(4).

In response to Article 16(2) the Commission has put into effect a 3 tier structure to carry out the information exchange. First the Information Exchange Forum (IEF) was established, a steering group chaired by DG Environment with participants from Member States, EFTA countries and future Member States who are obliged to implement the Directive, Industry (represented through UNICE) and non-governmental environmental groups (represented through the European Environment Bureau).

It was decided to carry out the detailed technical work with Technical Working Groups (TWGs) each dedicated to a specific work area, either addressing a vertical industry sector such as the production of cement and lime or a horizontal subject across IPPC industries such as monitoring or industrial cooling systems. The European IPPC Bureau was established to organise these TWGs and to draft reference documents reflecting the results of the exchange of information in the TWGs. The acronym of **B**AT **REF**erence (BREF) document came into use when referring to these documents.

In determining BAT, a selection of techniques is examined according to their environmental advantages, cross media and cost implications. Importantly for each technique the applicability is considered in terms of whether it is equally applicable to all installations in a sector, whether it is appropriate for new installations or there are some limiting factors as to where the technique could be applied. In this way information is presented to inform both the operator and the permit writer in considering what options may exist at any specific installation.

The TWG is the principal source of all information for a BREF and an expert within the EIPPCB is dedicated to each TWG and works with the group to collect and validate information. It is compiled it into a draft document which is circulated to the TWG for comments, additional information and is subsequently redrafted. The TWG meets in plenary usually only twice over a period of about two years with most of the work carried out between plenary meetings on an individual or sub-group basis. The bureau expert plays an important role in validating information and drawing the TWG towards consensus. Whilst a consensus view of the TWG is highly desirable, it is not always achieved and sometimes it is necessary to report different views of TWG members.

4 Energy efficiency as part of BAT in BREF documents

Article 9 of the IPPC Directive was amended to avoid conflict with the introduction of emission trading. Emissions of greenhouse gases and energy efficiency in units which emit carbon dioxide from the site are explicitly addressed within the amendment but notwithstanding these, energy efficiency measures can still be considered and discussed within the framework of BAT for other cases.

For most techniques assessed in the determination of BAT there is an inevitable question over the cost effectiveness of the technique in terms of environmental value gained for the investment to be made by industry.

Many techniques have a net cost and for them to be accepted as BAT requires that they meet the criteria of being economically and technically viable in the industry sector concerned taking into consideration the costs and advantages, as well as being good for the environment as a whole. Some techniques can have a net cost benefit, if they result in greater process efficiency, reduction of wastes or consumptions of raw materials, due to cost savings offsetting the investment and running costs.

It has often been said that the environmental regulator does not need to consider such techniques as waste minimisation or energy efficiency as it is a routine for companies to seek cost savings themselves. Provided that they know of the technique, companies are likely to voluntarily implement those which have an attractive payback period for the investment. However, they are much less likely to implement a technique which has either a long payback period, or is cost neutral.

With waste minimisation, it has been shown through a number of case studies that the potential cost savings are often under-estimated due to taking only the external waste disposal or treatment costs into account. Generally, waste minimisation will also result in better raw material efficiency and higher yield which means potentially higher sales revenue for the same raw material input or lower raw material costs for the same production level. From the environmental point of view, it is difficult to quantify the environmental benefit resulting from general implementation of waste minimisation techniques as this can depend on the specific waste disposal route on a case by case basis. However, reduced amounts of waste produced must logically have some environmental advantage and not a disadvantage.

The same is also true of energy saving techniques. It is difficult to quantify the overall environmental benefit of a particular energy saving technique because it will depend on the specific energy source on a case by case basis. However, reduced energy consumption must logically be an environmental advantage not a disadvantage. Therefore, if a specific energy saving technique is technically viable in the sector concerned (usually demonstrated by experience within the industry), the economic tests of BAT can logically be satisfied if it is shown that implementation of the technique would be, at worst, cost neutral over the economic lifetime of the investment. In the case that a short payback period is foreseen this makes the technique economically attractive to industrial operators and it may be implemented simply as a result of disseminating knowledge about the technique.

If it is shown that an energy saving technique still has an overall net cost after taking into account the cost savings over the economic lifetime of the technique, then the question remains whether the environmental advantage of the reduced energy consumption merits the cost involved.

Of course, there is a further test for an energy saving measure to be accepted as BAT in that it should be good for the environment taken as a whole. In this respect, issues such as the use of chemicals, a higher risk of accidents, reliability of operation and consequences on emissions, may mitigate against the technique being accepted as BAT.

Energy saving techniques tend to fall into one of two categories. Reduction of energy used in a process or recovery of energy produced in a process. In either case, there may be wider implications for the energy infrastructure on a site, particularly in the case of combined heat and power generation – an intrinsically energy efficient approach in the first place. The usefulness of recovered energy depends upon the quality of the energy (typically the temperature of heat transfer medium or pressure of steam recovered). The higher the quality of the recovered energy the more uses it may have in any given situation. High grade heat can in principle be used to generate electricity which is then available for wide distribution. Lower grade heat may only be usable locally for activities such as drying or pre-heating unless it can be converted into higher grade by the use of heat pumps. It makes no environmental sense to recover heat which cannot be utilised.

Within the exercise to determine BAT in BREFs, on a sector by sector basis, a particular problem with addressing energy efficiency is a lack of energy consumption and production data at the unit operation level. Increasingly there are a number of technical tools to optimise energy efficiency in installations but these all require data input which is not always available. Thus the first step towards energy efficiency must be the measurement and recording of energy inputs and outputs both in amounts of energy and quality.

The next hurdle to exchanging information on energy efficiency is the degree to which such data might be considered commercially confidential. There is clearly a competitive advantage to being more energy efficient than the competition.

In fact there are some clear examples from the BREF work to date where energy data is well known and used within the industry but is regarded as commercially sensitive so it is not made available to the IPPC BAT technical working groups. In one case, the precise energy efficiency of the European industry sector is key to maintaining a competitive European industry against potential extra-EU imports. In another case, the industry has largely entered into commercial and confidential agreements with an organisation who calculate an overall energy efficiency index for each installation in the scheme as part of an industry benchmarking exercise.

Energy efficiency within industrial installations is something relatively new for the attention of environmental regulators. IPPC requires that energy efficiency is addressed alongside other environmental impacts. It can therefore be foreseen that as the IPPC Directive is implemented across the EU-25, environmental regulators will gain knowledge and information about energy-efficiency techniques. Whilst respecting confidential and competitive issues as mentioned above, the ongoing exchange of information on BAT provides a forum for such knowledge to be validated and disseminated to regulators and industry alike. Having one focal point for such information can also help to disseminate knowledge between industry sectors which would otherwise not have such a link.

All BREFs and draft BREFs can be downloaded free of charge from the EIPPCB internet site http://eippcb.jrc.es.

The consolidated version of the IPPC Directive can be found at:
http://europa.eu.int/eur-lex/en/consleg/main/1996/en_1996L0061_index.html

Plenary opening session

AUTHORITIES ROLE IN THE ASSESSMENT OF ENERGY EFFICIENCY

***Marianne Lindström, Mikko Attila, Jaana Pennanen**,*
Finnish Environment Institute
***Elise Sahivirta**,*
Finnish Ministry of the Environment

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ABSTRACT

The general principle of efficient use of energy is stated in the European Directive on Integrated Pollution Prevention and Control (Directive 96/61/EC of 24 September 1996). This principle is quite new for environmental permitting and the European Union Member States have problems in implementing it in practice. Therefore, under the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL Network), Finland took the role of lead country for a project that aims at improving implementation of the Directive's principle of energy efficiency.

The project's overall objective was to identify what constitutes good practice when determining energy efficiency for industrial operations and to identify areas of key difficulties incorporating energy efficiency into the permitting process of Member States. The results of the project were that it would be good practice to create practical guidelines to define energy efficiency such as benchmarking and energy balance checking. Negotiations between operators and authorities, and application forms made available on the Internet, also would be good practice. Since energy efficiency as permit condition was found to be a difficult question, one measure of good practice would also be to link the permit condition about energy efficiency to voluntary energy saving agreements that are already successfully in use. In addition, various new and more specified Best Available Technique Reference Documents are needed.

1 Background

The IMPEL Network is an informal network of the environmental authorities of EU Member States and Future Member States that has been active since year 1992. This paper is based on the report of a project named "Energy Efficiency in Environmental Permits" within the IMPEL Network (Lindström et al. 2003). The content of this paper and the larger report does not necessarily represent the view of the national administrations or the European Commission.

The key priority for the EU's Sixth Environment Action Programme is the ratification and implementation of the Kyoto Protocol to cut greenhouse gas emissions by 8% over 1990 levels by 2008–12. This must be considered as a first step to the long-term target of a 70% cut (European Commission 2002). EU's greenhouse gas emissions fell by 3.5% between 1990 and 2000, but without additional counter-measures they are likely to rise back to around the 1990 level by the year 2010 (Haworth et al. 2000).

The general principle of efficient use of energy is stated in Article 3 of the European Council Directive 96/61/EC on Integrated Pollution Prevention and Control. Article 6 of the Directive stipulates the application requirements that an applicant must be aware of, and Article 9 deals with the duties of the permit authorities concerning Best Available Technology (BAT) and energy efficiency. Article 15 includes provisions about the access to information and public participation in the permit procedure. As of the time of this study, there is only little experience so far with energy efficiency provisions in integrated permits.

Article 9(8) of the IPPC Directive gives the Member States an opportunity to use General Binding Rules (GBR) in implementation of energy efficiency requirements. The GBRs are, or would all be considered as, minimum energy efficiency requirements, but there would still be a possibility to impose stricter requirements case by case. The GBRs are not generally used in clarifying energy efficiency, but there are some branch general binding rules, for example in France, that include at least some consideration of energy efficiency, like clarification of energy consumption and justification of the choice of energy source. Only France has actually used GBRs with some consideration on energy efficiency. However, France pointed out that general binding rules should here be understood as binding guidance. Also, other countries are considering the possibility of using GBRs in the future.

The legal and administrative "command and control" regulatory approach has been the traditional way to guide environmental protection in the EU. The same approach was adopted in the IPPC Directive (Backes & Betlem 1999). In contrast, market-based voluntary methods emphasise less control by authorities and the operators' obligation to "play by the rules". In these cases, the minimum compliance requirements are fixed through the permitting system that is supplemented by voluntary methods. Some of the Member States have chosen market-based measures, such as energy saving agreements, the EU Eco-Management and Audit Scheme (EMAS) and ISO 14001, in addition to "command and control" regulation to implement the articles concerning energy efficiency of the directives. The problems with energy efficiency regulation is that various methods have little, if any, connection with each other and the control system of energy efficiency is basically sector-oriented. See Figure 1.

FIGURE 1. The present ways to control energy efficiency.

All of the participating countries have several organisations involved in issues concerning energy efficiency. While the assumption was that there might be some problems in cooperation, because of the involvement of several different authorities, this was not generally seen as problematic. There is a great deal of cooperation between the authorities, and even countries where no cooperation was pointed out, did not see any problems arising from the division of authorities.

2 Objectives

In the terms of reference, the main objectives of the project were:

- to investigate different opinions on how energy efficiency can be regulated in IPPC permits;
- to make a study on how energy efficiency is dealt with in the existing documents, the Best Available Techniques Reference Documents (BREFs) and voluntary environmental management schemes;
- to examine how voluntary environmental management schemes and energy saving agreements can be linked to the legal obligations in environmental permitting;
- to study the cooperation between environmental and energy administrations in the implementation of the IPPC Directive and
- to study the role of the authorities in the assessment of energy efficiency in applications and environmental permitting of large installations.

3 Methods

A three-step process was used to obtain the necessary information. First a draft questionnaire was drawn up and discussed in a meeting of members in the advisory committee, which consisted of members from Austria, Finland, Germany, the Netherlands, Sweden, and the IMPEL coordinator. The finalised questionnaire was sent out to the participants of the project in June 2001. The replies to the questionnaire were analysed. The second step was to hold a seminar to get more in-depth information, where the most problematic questions were discussed, key difficulties identified and good practices for different situations were agreed on. The third step was to examine eight BREF documents and make studies on technical possibilities to use energy efficiently and on options for emissions trading in the European Union. A detailed breakdown of the various BREF documents is provided in Table 1.

The questionnaire covered specific topics from the IPPC Directive and its implementation in the countries. In particular the contents of Articles 3(d), 6(1), 9(1), 9(8) and 15(1) were looked at because they are most relevant to Member States in incorporating energy efficiency into the permitting process. The questionnaire also covered other topics such as competent authorities, voluntary environmental management systems, energy saving agreements, energy taxes and emissions trading. The aim of the questionnaire was to clarify the similarities and differences between the countries in implementation of the IPPC Directive and in the practices of the authorities permitting IPPC installations. The following countries replied to this questionnaire: Austria, Denmark, Finland, France, Germany, Ireland, Italy, Lithuania, the Netherlands, Poland, Portugal, Sweden and the United Kingdom.

After the questionnaires were processed, a seminar was organised in February 2002 to further address energy efficiency issues for the Member States. The seminar themes were the legal base for energy efficiency, consideration of energy efficiency in environmental permitting, energy issues in environmental management schemes and energy saving agreements and emissions trading. At the seminar, where participants from 9 Member States and 2 Future Member States attended, key difficulties in the handling of energy issues in environmental permitting were discussed and possible solutions to the problems were suggested. Finally, good practices for the consideration of energy efficiency in environmental permitting of large installations were agreed upon. The seminar report was sent out to the participants for comments, which have been incorporated into the final report. The final report was adopted at the IMPEL Plenary Meeting in December 2002.

4 Results

4.1 Key Difficulties

According to the replies to the questionnaire and the discussions in the seminar, the following issues were seen as key difficulties.

The definition. The definition of energy efficiency in connection to the permitting procedure is not clearly defined. Overall guidance on energy efficiency is not possible, but the solution could be found in sector-wise guidance and efficiency could be looked at on a case by case basis. The definition of efficient use of energy must balance the reduction of energy use with the other environmental impacts; reducing emissions of pollutants can for example, increase energy consumption. Also, the lack of references and inspection methods make it more difficult. The economic aspects play a more dominant role than in the other environmental fields. Energy efficiency in environmental permitting is not a concept familiar to the environmental authorities.

Binding permit conditions. One of the most difficult questions for the permit authorities was defining a binding permit condition for energy efficiency. In most cases it is not considered possible to set up enforceable conditions for energy efficiency in a permit for an individual installation. The energy data could also be confidential. The permit conditions are not always concrete enough. It is difficult to make a specific condition for energy usage, for example, energy used per produced unit, because of many varying variables, such as basic consumption, several product lines and fast changes from one product to another.

Enforcement and supervision. As a clear definition of energy efficiency is not available, direct enforcement and supervision by environmental authorities is more difficult. Too general and vague permit conditions are not enforceable and they are difficult to supervise. Non-binding permit conditions are not enforceable at all. There is also a lack of knowledge among inspectors.

Publicity/confidentiality. In some countries industry is prepared to disclose more information than in others and it is a slow process to change attitudes. Data on energy issues might be considered as sensitive. The operator can of course separate the information in the applications into confidential and non-confidential. In France the energy authority will not publish any results on energy consumption if the number of operators is below three or one operator represents about 70% of the consumption. In Austria concrete data are only available for legitimated parties in the permit procedure.

Relations to emissions trading. Greenhouse gas emissions trading will affect the application of the IPPC Directive. Until now there has not been a clear picture of how the links between emissions trading and IPPC permitting will work. It was anyhow pointed out by the EU Commission that CO_2 falls within the IPPC Directive's broad definition of pollution (Art. 2 (2)).

Voluntary systems versus permit. Also the interrelationship between the voluntary agreements and permit conditions is part of this problem. The targets of voluntary agreements and the means of permitting do not always coincide, for example, the requirement of continuous improvement is too vague as a permit condition. The permit conditions should be based on BAT. The participants had different opinions on the use of voluntary energy saving agreements as a part of the permit. Some countries saw it as impossible to link the voluntary agreement system and permit system together, while some thought that there could be a partial connection for some detailed issues.

Lack of information and expertise. Generally there is a lack of expertise and information on how to apply energy efficiency in the permit procedure. The BREFs contain some but not enough process specific energy information. The participants in the seminar pointed out that there is not enough cooperation between energy and environmental authorities. The auditing information from the voluntary energy saving agreement is not available in formats that could be used in the permit procedure. There is not enough training for practical implementation of the energy efficiency demand.

4.2 Good Practice

In the seminar discussions following topics were considered to be good practice.

The definition. It is good practice to create practical guidelines for permit writers to define energy efficiency in order to clarify the issue. Overall guidance of energy efficiency is not possible, but the solution could be found in sector-wise guidance and, in general, energy should be looked at on a case by case basis. In France there are some sector-wise general binding rules and in the United Kingdom non-statutory guidance. Several approaches are good and can be used in parallel. As good practical solutions benchmarking, pinch technology and energy balance checking were mentioned.

Beforehand discussions and application forms. A good application is a requirement for a smooth permitting process. In order to create good applications prior information exchange between the operator and the authorities is good practice. A good practice would be that, application forms where the information requirements concerning energy efficiency are listed should be available on the Internet. In Finland and in Portugal there are such application forms available.

Energy efficiency as a permit condition. This project could not identify any good practice for establishing binding permit conditions. However, the final report gives some concrete examples of more or less binding permit conditions. The permit condition or the text in the descriptive part could also be linked to voluntary energy saving agreements, which functions very well in the Netherlands and Finland.

BREFs. It is good practice for the environmental authorities to use the BREFs which contain a considerable amount of information on energy. The most specific information is available on energy consumption. There is less data on energy saving and energy recovery techniques.

Monitoring and supervision. Monitoring and supervising of energy efficiency in permits is very difficult due to often general and vague permit conditions. In inspections of energy efficiency good practice is self control under the precondition that the inspector can influence the monitoring practices of the operator. Because of the lack of energy knowledge among the permit authorities and inspectors, there is a need for more cooperation between the energy and environmental authorities.

Audits. Information on energy audits can be used as a tool to give information to the environmental authorities. As in Ireland the planning of the audit of energy efficiency of the site should be developed together with the environmental authority. The audit report should also be available on site for environmental inspectors and the summary of audit findings should be submitted as a part of any annual environmental report.

Cooperation. Cooperation between energy and environmental authorities in energy efficiency issues is good practice and should be developed. Each authority has special knowledge that the others may need or could use in their work. Especially in this case development of cooperation is highly recommended since energy efficiency is not a very clear and simple concept. The development can be done in several ways such as joint seminars, working groups and cooperation in drafting the environmental legislation. Audit reports can be used as a tool to give information to the environmental authorities. Also, cooperation between the Member States and future Member States in implementing the requirement on energy efficiency is good practice and the IMPEL Network as such promotes this kind of cooperation.

Access to information and public participation. It is good practice to have transparency in environmental permitting concerning energy efficiency, too, so that the Aarhus Convention really is implemented in the same way in different countries. Good practice is that the application forms and the permits are available on the Internet. The development of general guidelines for what can be declared as confidential is also essential. Transparency in all voluntary measures is also good practice.

Relations to emissions trading. The link to energy efficiency requirements under the IPPC Directive needs to be further developed. If the cost of production of energy rises as a result of emissions trading, this will assist energy efficiency requirements under the IPPC Directive. One of the advantages of emissions trading is that reductions can be achieved in a more cost-effective way because market forces will be operating.

Voluntary measures. The environmental management systems provide a good tool for managing energy issues. The policy and targets set by the company should not be transferred as such to the permit. This could negatively affect the companies' interest in setting targets and even in using environmental management systems. There should also be clear and attractive incentives for the companies to join the management systems.

It is in itself good practice when voluntary energy saving agreements are made for most of the industries in a country, which should lead to energy savings and the efficient use of energy. Concrete measures are already included in the agreements and should be followed up.

Training. As the environmental authorities in general do not have enough knowledge of energy efficiency it is good practice to provide general training for environmental authorities and to raise the level of knowledge. It is also good practice to create fact sheets that contain information on energy efficiency as a tool for environmental permitting, to supplement the BREFs and any national BAT guidance. Good practice is that the environmental authorities are provided with information from the voluntary energy audits made by energy experts.

4.3 Energy Efficiency in the Environmental Permit Procedure

It was found that most of the participating countries in this project required differing levels of information in their permit applications as shown in Figure 2. Earlier saving measures and the amount of energy used for environmental protection measures were not always required. An overview of country specific requirements follows.

As guidance to the operators Finland has a general application form, and additionally a form specifically for energy issues with guidance for the operators to fill in when applying for an environmental permit. A task group with members from the Finnish environmental authorities and the Confederation of Finnish Industry and Employers developed this form for energy issues. Operators must include in the form information concerning the following:

- total energy balance;
- energy production;
- energy consumption;
- assessment of energy efficiency;
- energy plan;
- energy used for environmental protection measures;
- description on energy use;
- earlier and planned saving measures; and
- planned environmental investments.

The environmental authorities take into consideration specific energy saving matters such as choice of fuel, use of electricity, use of heat, process optimisation, index for energy efficiency, use of waste energy, previous measures for energy savings, planned measures for energy savings and planned measures for environmental investments.

Other items the authority takes into consideration when evaluating energy efficiency can include the use of non-fossil fuels, transportation, water consumption, air pollution abatement and waste management. The use of non-fossil fuels is always taken into consideration whilst transportation is seldom taken into account – only Sweden and the Netherlands consider it to be a part of permit consideration. In Sweden energy used in producing raw material or chemicals used might be considered. Sweden also considers issuing permits with permit conditions including specific energy consumption. Water consumption, air pollution abatement and noise abatement are always taken into consideration in the permit procedure because the minimisation of all pollutants is important.

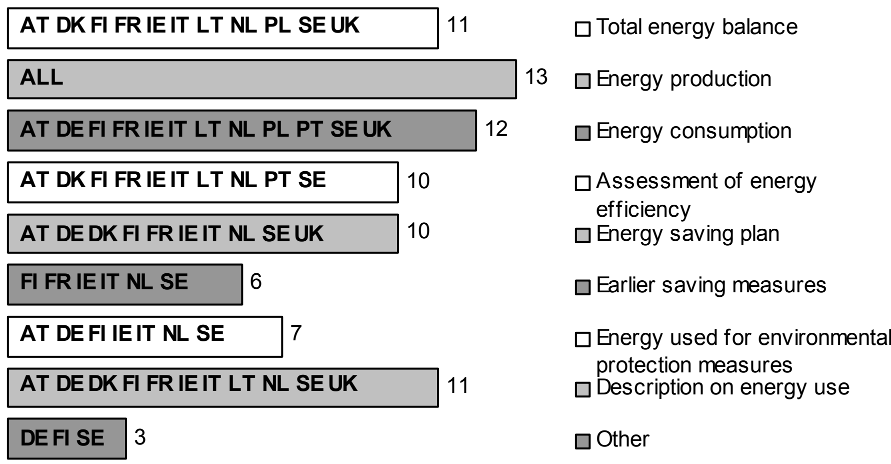

FIGURE 2. Information Concerning Energy Required in the Permit Application 1

4.4 Energy Efficiency in Permitting in Practice

In the seminar discussion it was pointed out that the requirement for energy efficiency is as important as the permit conditions on emissions. There are not yet many examples of permits containing consideration of energy efficiency. In general, the countries do not have guidance for the consideration of energy efficiency in the permitting procedure. Most of the countries considered the following items as important when evaluating energy efficiency in the permit procedure:

- choice of fuel;
- use of electricity;
- use of heat;
- process optimisation;
- other technical measures;
- index for energy efficiency or specific use of energy;
- use of waste energy;
- previous measures for energy savings;
- planned measures for environmental investments and, if applicable
- possible production of CHP.

In Germany there are usually references to the application. However, permit conditions will be required if the authority has to fix other or additional measures than those described in the application documents. If applicable, CHP is also taken into consideration in permitting.

In Finland there is a permitting guidance under development in which the issue will be addressed. Additionally, also in the Finnish environmental permits there could be references to the application. In cases where the installation has joined the energy saving agreement no further energy efficiency conditions are usually set in the permits.

[1] AT = Austria, DK = Denmark, FI = Finland, FR = France, DE = Germany, IE = Ireland, IT = Italy, LT = Lithuania, NL = the Netherlands, PL = Poland, PT = Portugal, SE = Sweden, UK = the United Kingdom.

In France there are “Provisions about rational use of energy in classified installations for environmental protection regulations”. E.g., in the ministry decision on the paper industry it is required that the plant manager must take all necessary measures in design and management of the plant to reduce air pollution at the source, in particular by optimising energy efficiency.

In France the efficient use of energy in a plant is mainly studied when designing the plant together with the impact study, at the decennial assessment of the permit or during energy audits on a voluntary basis. France has a “Decree on the Periodic Control of Installations Consuming Energy”. Periodic controls, which are carried out at the expense of the owner of the thermal installation, comprises:

- calculation of the yield characteristic of the boilers;
- control of the existence and the correct operation of the control and measuring apparatus;
- checking of the good condition of the installations intended for the distribution of thermal energy;
- checking of the quality of the combustion and the correct operation of the boilers; and
- checking of the boiler manual.

In Ireland the current permits often have a condition that requires the activity to carry out a thorough energy audit that will identify all opportunities for energy use reduction and energy efficiency. The Netherlands thought that benchmarking is a good way forward, at least for the most environmentally aware companies. In the United Kingdom an energy efficiency implementation plan should be attached to the permit. The most difficult question is whether the authorities can set limit values for energy efficiency. The general opinion was that there could be no restrictions on energy consumption as such and that it is difficult to have binding conditions. The linkages between the permits and the voluntary energy saving schemes were seen as useful. The checking of energy use could be done through annual monitoring.

In Lithuania there are requirements for energy use and references to the application in the permits. In Poland the permit must specify, in particular, the type and quantity of consumed energy, materials, raw materials and fuels, the sources of origination, of substances, and energy releases to the environment.

Portugal has so far limited experiences with permitting IPPC installations. The use of waste energy, previous measures for energy savings, planned measures for energy savings and planned measures for environmental investments are also considered when providing grants to industry within several financing programmes with the objective to improve energy efficiency.

4.5 Energy Efficiency in BAT Reference Documents

The BAT Reference Documents are intended to aid various industrial sectors in their environmental permitting procedure. The inclusion of energy efficiency guidance is important in implementing the IPPC Directive on energy efficiency. There are 32 industrial sectors for which BREFs have to be established by 2004/2005. By November 2002, only eight BREFs have been adopted. Nevertheless, a general tendency can be recognised because of the diversity of the analysed industrial sectors. These BREFs include the following industries which are also detailed in Table 1 (see also References):

- cement and lime industry;
- iron and steel production;
- non-ferrous metals industry;
- pulp and paper industry;
- chlor-alkali manufacturing industries;
- ferrous metals processing industry;
- glass manufacturing industries; and
- cooling systems.

All the analysed BREFs contain a considerable amount of information and data on energy (see Table 1). The most specific information is available for energy consumption. As far as energy saving and energy recovery techniques are concerned, there is less information. In general, there is a need for more information regarding all the energy aspects (consumption, savings and recovery measures and values). BATs are generally subdivided into general and process specific BATs. In a few cases, each process specific BAT within an industrial sector is shown in a table and described separately.

The purpose of the BAT review is thus to provide general indications regarding the emissions and consumption levels that might be considered as an appropriate reference point to assist in the determination of BAT based permit conditions or for the establishment of general binding rules. In other words, environmental permit conditions should be based on BATs, and BREFs (which are not binding) should be taken into consideration as one important source of information on BAT.

4.6 Voluntary Energy Saving Agreements

The consideration of voluntary energy saving agreements in the permit procedure varies between the countries but they are not preferable to permitting. Regardless of the way voluntary agreements are applied, they are considered successful at least in the cases they cover most of the large industries and the results of them are followed up and controlled. The link between the voluntary energy saving agreement and permit conditions is in general weak but could be strengthened.

The concept of voluntary energy saving agreements is in use in eight of the countries participating in this project. It is currently not in use in Austria, Lithuania, Poland, Portugal and Sweden. The first agreements were concluded in the Netherlands in 1992, where the implementation of the energy agreements depends on the category of the installation. In most Dutch cases, companies join an agreement and plan their own objectives. For major energy consumers a long-term agreement on energy efficiency is in use and the reduction targets are agreed at the branch level. The agreements follow a particular national form in the participating Member States.

There are many different ways that companies take part in the agreements. In most countries the objectives of the agreement apply to the companies or industrial branches. In Germany they apply only to the branches and in Finland only to the companies. The Irish approach is that the objectives generally apply to a particular site location and in the Netherlands they will apply also to the operator. If Sweden were to have these voluntary agreements in use, all alternatives and combinations of them would be considered. The connection to the IPPC Directive can be seen as a joint venture in seeking methods and tools for the determination of and follow-up to energy efficiency in various sectors.

5 Conclusions

Defining energy efficiency in practice is considered to be very difficult because of the differences in the nature of the installations to which energy efficiency applies. Energy efficiency is an issue to be considered in the permitting procedure among other technical conditions. For a smooth permitting procedure information on energy efficiency either in general binding rules, sector-wise guidance or application forms including guidance on energy efficiency are required. The participating countries had only few examples of permit conditions concerning energy efficiency.

Voluntary systems, especially energy saving agreements, provide useful information on energy efficiency, use and savings that could be more utilised in the permitting procedure. Also the BREFs contain a considerable amount of information and data on energy. The most specific information is available on energy consumption, but there is a need for more information regarding energy efficiency techniques. The link between permitting and voluntary systems should be clarified.

The trading of emissions is a new instrument in environmental policy and until now there are very limited experiences of the European trading scheme. The relations between the CO_2 emissions trading scheme and the energy efficiency requirements under the IPPC Directive is not entirely clear and should be improved.

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Table 1. Summary of Energy Efficiency (EE) Aspects in the BREFs.

	Cement and lime	Iron and steel	Non-ferrous metals	Pulp and paper	Chlor-alkali	Ferrous metals	Glass	Cooling systems
Importance of EE compared to other environmental issues	Very important (air emissions)	Very important (air emissions)	Important (air emissions)	Important (water discharges)	Important (air/water emissions)	Important (air emissions)	Very important (air emissions)	Important
Which is the most important and energy intensive process/technology?	Clinker burning, lime burning	Blast furnace	Pyrometallurgical processes	Depends on the plant, evaporation/paper machine	Mercury (amalgam) technology	Heating and heat treatment furnace	Melting	Closed circuit dry cooling, dry air cooling
Is energy data available?	Yes, only for consumption	Yes (good description)		Yes	Yes, only for consumption	Yes (good description)	Yes (good description)	Yes, only for consumption
Are energy recovery/savings techniques for this process mentioned?	Not in detail, partly also considered as BAT	Yes, a lot, partly also considered as BAT	Yes, consumption and recovery	Yes, techniques in general considered as BAT	Yes, in terms of process selection	Yes, a lot, partly also considered as BAT	Yes, a lot	Yes, but rarely
Is energy data for other processes (incl. techniques) available?	Yes, in general for consumption	Yes	Yes, consumption and recovery	Yes, consumption data	Yes, consumption data	Yes (good)	Yes, mainly for consumption	Yes, consumption data
BAT **General BAT available**	Yes (primary measures	Yes	Yes	Yes	Yes (primary measures	Yes	Yes (design phase)	Yes (design phase)
BAT for specific processes	Yes, limited	Yes, BATs for all types of plants	Yes	Yes	Yes, limited	Yes, good description	Not mentioned as BAT (to consider in the determination of BAT)	Yes
Energy data in BAT	Yes, only consumption (limited)	Yes, table for each BAT	Yes	Yes, almost in every BAT	Yes, limited	Yes, data about consumption, saving recovery	Not concerning EE, only emission levels	Yes, partly
Are energy recovery/savings measures site specific?	No	Not mentioned	Yes	Yes, a few (CHP)	Yes, because of difficulties in storage and transport	Not mentioned	Not mentioned	Yes, but difficult to quantify
Are any recommendations for the next update mentioned?	Survey of current techniques consumption is useful	Not available	More information about consumption data	More information on the assessment of energy efficient techniques	Not available	Provide more information on emission and consumption level	More techniques for EE improvement would be useful	Not available
Special comments	Energy costs = 30–50% of total production costs. Associated BAT heat balances value is 3000 MJ/t clinker.	There are many different kind of plants; each has different processes and techniques.	Limited information about EE in BATs, in general OK.	A lot of information concerning EE for each single process. A lot of energy recovery techniques are not considered as BATs yet.	Information about process conversion (technologies) and about legislation for some EU countries. Associated with BAT: < 3200 kWh/t chlorine large consumption of electricity.	Balance between EE and air pollution (for certain techniques). Very detailed description of BATs.	BATs are concentrated more on emissions. Melting process needs about 75% of all energy usage.	BATs are described, but only a few have a lot of data → the final BAT solution will be a site-specific solution. Calculation model for energy conservation and saving is given.

Plenary opening session

IPPC VERSUS EMISSIONS TRADING

Lesley James
Friends of the Earth (England, Wales and N. Ireland) and
The European Environmental Bureau

IPPC VERSUS EMISSIONS TRADING

Lesley James, *Friends of the Earth (England, Wales and N. Ireland) and The European Environmental Bureau*

ABSTRACT

IPPC is the key instrument of EU industrial policy relating to the environment. This brings the flexibility required for emissions trading into regular conflict with the relative inflexibility of site-specific IPPC permits. Trading beyond BAT provides insufficient scope for any serious scheme, so ways of resolving this conflict are being sought by those promoting emissions trading.

The Commission has recently acted to remove one option i.e. exploiting the flexibility component of site-specific BAT by downgrading it to the minimum level required to protect local environmental quality standards. Such exploitation now risks the imposition of general binding rules by the Commission.

The Greenhouse Gas Emissions Trading Directive set the precedent for another 'solution' by granting a derogation from IPPC for those installations involved in trading. However, it is highly debateable as to whether this preserves the energy efficiency requirement, integrated nature and level of ambition of IPPC.

Neither does the US experience with acid gas trading provide justification for resolving the conflict by replacing IPPC altogether. It has a significantly lower level of environmental ambition than command-and-control systems within Europe, and takes no account of the impact on cost savings of either that low level of ambition or the need to preserve local air quality standards. Further, it is questionable whether those cost savings that were achieved can actually be attributed to trading.

It might therefore appear that the solution lies in experimenting with trading and if it underperforms, then reverting to IPPC. Unfortunately, though, financial realities are against this. So trading is essentially a one-way commitment, but when that commitment has already been made – as it has with greenhouse gas trading – no attempt is being made to check the relative performance of the two systems of industrial management. It is therefore concluded that no justification as yet exists for wholly or partially replacing IPPC with trading.

MAIN TEXT

This perspective on the relationship between IPPC and emissions trading is not based on any ideological position either for or against emissions trading. Some people object to trading on the grounds that it grants a right to pollute and then puts a commercial value on that right to pollute. However, these things already exist with other systems of industrial management – it's just that trading makes them more explicit. Then some people also object to trading for pollutants that have local impacts, arguing that trading could concentrate pollution in particular areas, giving rise to pollution hotspots. It could – but this is a constraint on trading, not a barrier to it, because it could be dealt with by fixed backstop limits without ruling out trading altogether. So this paper takes the practical approach of looking at results i.e. how does trading compare to other systems of industrial management when it comes to protecting the environment.

IPPC is, of course, the key instrument of EU industrial policy relating to the environment, and this brings the flexibility required for trading into regular conflict with the relative inflexibility of site-specific IPPC permits. There is flexibility in IPPC, but it's not the sort of geographical flexibility required for emissions trading. So … where does that leave trading?

Well, it leaves it with several potential options, the first of which is to implement IPPC and then trade beyond it. But if that option doesn't provide enough scope for trading, then it could exploit the flexibility component of IPPC, or it could seek a derogation from it, as has occurred for CO2. Alternatively, it could replace IPPC altogether, or, if that seems a bit extreme, then there's the possibility of experimenting with trading. Each of these options will be examined in turn, starting with trading beyond IPPC.

There is some scope for this; for example, IPPC doesn't cover all categories of plant, although most major ones are included. And some installations lie outside the capacity thresholds of IPPC -- for example, combustion plants <50MWth. Then, of course, it's quite possible to go beyond BAT – indeed, Article 10 of the IPPC Directive specifically requires this if it is necessary to meet local environmental quality standards. And, in the immediate future, existing plants are entirely free to trade, right up until 2007 when they have to comply with IPPC. However, the combined potential of these possibilities for trading beyond IPPC still leaves relatively little scope for trading, which is why this paper is titled 'IPPC vs emissions trading' not 'IPPC and trading'.

One way of increasing the scope for trading is to exploit the flexibility component of IPPC. Article 9(4) of the IPPC Directive requires that permits '… shall be based on the best available techniques … taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions.' So IPPC provides flexibility to take account of local factors, but in remaining site-specific it doesn't provide the geographical flexibility required for trading. But the local flexibility component that does exist in IPPC could be exploited by downgrading the site-specific BAT to the level required to simply meet environmental quality standards, thus providing more scope for trading.

However, this would not then be IPPC, and as such probably represents the worst option of all – pretending to implement one system of industrial management when you are in fact essentially implementing another. It represents a massive waste of resources, as well as inhibiting the sort of review processes that are essential to the evolutionary development of any system of industrial management. Therefore the

Commission's statement/threat -- that it will consider imposing general binding rules if Member States are not implementing IPPC properly – is to be welcomed [1].

The next option is to seek a derogation from IPPC for those installations interested in trading. The precedent for this has already been set in the amendment to IPPC contained in the Greenhouse Gas Emissions Trading Directive. The initial proposal produced in late 2001 excluded greenhouse gases from IPPC as long as they don't cause significant pollution, but Article 2(2) of that proposal made quite clear that this exclusion was without prejudice to the energy efficiency requirement of IPPC [2]. This, it was argued, would make the two directives compatible. But this supposed compatibility is highly debateable for three reasons: problems with energy efficiency, equivalence and integration.

Taking energy efficiency first … despite the apparent guarantee of the 'without prejudice' clause, there was immediate concern that this was being downgraded – and this concern was fuelled by a non-paper produced by the Commission to clarify the situation. Basically, Article 3(d) of the IPPC Directive requires that 'Member States shall take the necessary measures to ensure that installations are operated in such a way that energy is used efficiently' and Article 9(1) defines this as being ' … to achieve a high level of protection for the environment as a whole.' But the Commission's paper stated that the energy efficiency requirement of the IPPC Directive is ' … a baseline or bottom line for the consumption of electricity or heat which European industry should not be able to go below.'[3]

This might have been just an unfortunate use of language, with the Commission simply meaning that trading can occur beyond BAT for energy efficiency, which it can. However, with CO2 emissions so inherently linked to energy efficiency, there was a very real fear that the BAT standard would be downgraded to increase the potential, and these fears appear to have been realised with the adoption of the final form of the Greenhouse Gas Trading Directive last year [4]. This retains the clause excluding greenhouse gases from IPPC as long as they don't cause significant pollution, but removes the 'without prejudice to IPPC energy efficiency' requirement. Article 26 makes quite clear that imposing energy efficiency requirements is now optional under the Greenhouse Gas Trading Directive. This is a long way removed from the command-and-control requirement under IPPC for energy efficiency to achieve a high level of protection for the environment as a whole, and it is very likely that trying to make IPPC compatible with emissions trading has cost a degree of energy efficiency.

But it is not possible to know this for certain one way or the other because of the problem of ensuring equivalence between the two policy measures. The Explanatory Memorandum accompanying the initial proposal for the Greenhouse Gas Trading Directive stated that ' … the quantities [of allowances] should ensure that the overall emissions of all of the participating installations would not be higher than if the emissions were to be regulated under the IPPC Directive'[para.13]. In fact, it's arguable that trading should actually go beyond IPPC and deliver greater emissions reductions, because if it is a more cost effective way of achieving reductions, then that should be reflected in the level of ambition. But unfortunately, it would appear that, either way, no-one's counting. The Greenhouse Gas Trading Directive contains plans to extend it to other sectors and greenhouse gases and to link it to other trading systems, but there appears to be no requirement to actually check the performance of emissions trading compared with IPPC. What we should be doing is setting CO2/energy efficiency BAT standards through an IPPC permit, even if there is no longer any requirement to apply these on a site-specific basis. The standards that are set should then be used to model those reductions that would have been achieved under IPPC and to effect comparison with those actually achieved under trading. And this problem of equivalence will be made worse by plans to allow trading beyond the EU scheme, unless the environmental quality of all allowances can be assured.

The third problem with derogations is that of integration, which has two components to it – permitting and environmental impacts. Permitting shouldn't be a issue, because it would be quite possible to integrate the IPPC and trading permits. However, environmental impacts would most definitely be a problem. IPPC methodologies for BAT assessments involve: indices for the impacts to air, land and water; noise, odour and visual impacts; photochemical ozone and global warming potentials; consequences of accidents; and the impacts of waste disposal options. These components then have to be balanced or traded off. This is a complex and sophisticated approach to environmental management, and as such, it can only be damaged by the removal of particular pollutants and their consideration in relative isolation, rather than as part of an integrated approach.

So, these three problems -- energy efficiency, equivalence and integration – undermine the Commission's claim that a derogation makes greenhouse gas emissions trading compatible with IPPC; it simply doesn't. And particularly important amongst those questioning this is FIELD/IEEP, who are on record as saying that 'Concerns could be signalled on the extent to which the Commission proposal still achieves a high level of protection.' [5]. This is particularly ironic, given that it is they who drafted the Greenhouse Gas Trading Directive and its amendment to IPPC.

And neither is the European Parliament very impressed by it. In a report adopted in January 2004 by the Environment Committee, it 'calls for Directive 96/61/EC to be applied to the air pollutants on which the emissions trading system is based'. This was reinforced by a non-binding resolution adopted in plenary session in February 2004, in which the Parliament stated that the removal from IPPC of gases covered by the EU's climate emissions trading directive 'is to be deplored' [6] They have done this firstly because they are concerned that installations involved in trading are escaping the rigours of BAT. Then secondly, they are concerned to protect the integrated nature of industrial management, in particular the balancing of impacts already described, and the inclusion of downstream impacts such as photochemical ozone.

But then, does any of this actually matter? The US experience with acid gas trading is reported to have been a great success, so can't this be used to justify abandoning IPPC altogether? However, in order to determine this, the criteria for that success and the basis of their evaluation have to be examined, and in doing so, problems arise. The criteria for the US 'success' are the cost savings that can be made in attaining a stated objective i.e. a 50% cut in sulphur emissions from the power sector, to be achieved by 2010 from a 1980 baseline. However, nowhere in the USEPA's official reports [7] [8] do they make the international comparisons that would show how abysmally low that emissions target is. For example, the UK will have cut sulphur emissions from its power sector by just over 90% over the much shorter period between 1994 and the start of 2008 [9] [10], and similar levels of sulphur emission reductions were achieved much earlier in Germany between 1982 and 1988 [11]. Both were achieved by traditional command and control systems of industrial management.

Then the USEPA claim to have gone 30% beyond their target reductions in Phase I of their acid gas programme. However, as they acknowledge in their own reports, this was due to the banking of allowances in anticipation of the stricter controls that it was known would follow in Phase II [7]. Their latest reports show Phase II emissions exceeding the current allocation of allowances, with the difference being covered by allowances banked in Phase I [8]. Therefore any 'overachievement' of emission reduction targets is simply temporary.

With regards to the stated objective of reducing costs, to their credit, the USEPA does question whether those cost savings achieved were actually due to trading [7]. They provide a spectrum of views, including one study arguing that for plants using low sulphur coal, none of the cost savings were achieved by trading; rather they were due to technological improvement and a fall in the price of low sulphur coal [12].

However, beyond that, they fail to give any consideration to the impact that the level of ambition would have on cost differences between traditional control and trading. For example, where FGD units have been required under traditional control systems, a target of 50% sulphur reductions could be increased to 90%+ with only an increase in operating costs. However, where trading has allowed plants to 'share' FGD units to achieve a 50% emission reduction, a 90% target would involve not only increased costs but also significant new capital investment. This would significantly reduce any cost advantage that could be attributed to trading.

Any such cost advantage would be further reduced by the strict enforcement of local air quality standards, which act as a constraint on trading, and which are required under IPPC. The results of the US system are reported in terms of overall impact, and it is a matter of considerable concern that at the end of the first five years of trading, the US authorities were still trying to reassure environmentalists about pollution hotspots.

So, if the US isn't the shining example that it's sometimes claimed to be, then there would appear to be a lack of empirical evidence as to the superiority of either system. So perhaps this ought to be resolved by experimenting with trading. Unfortunately, though, holding a trial and then reverting to IPPC if trading doesn't outperform is not a practical proposition. As has been pointed out by OXERA, the big economic consultancy that advises the UK Government and Environment Agency, companies wouldn't be able to raise finance for investment in new equipment if the industrial management system that was expected to deliver the returns on that investment could be terminated before the loan was repaid.

It would therefore appear that experimenting with trading is a one-way ticket. And yet, when that ticket has actually been bought -- as it has with greenhouse gas trading – then it appears that no comparisons whatsoever are being undertaken. This poses the question:

Do we throw away the key instrument of EU industrial policy in favour of a market-based system that has yet to demonstrate its ability to achieve at least equivalent results?

In answering it is appropriate to refer back to the overall position statement on trading that underpins this perspective i.e. an emphasis on results. And on that basis, the answer has to be 'no' – there hasn't been any case made for wholly or partially replacing IPPC with trading.

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Plenary session
Producing more with less: Efficiency in Power Generation

ENERGY-EFFICIENCY IN IPPC PERMITTING - A CHALLENGE TO THE LICENSOR

Jerry Roukens
RouCo BV
Tel/fax:+ 31.10.2480285 Email: g.roukens@chello.nl

ENERGY-EFFICIENCY IN IPPC PERMITTING - A CHALLENGE TO THE LICENSOR

G. Roukens, *Consulting ans buisness development*

Ladies and gentlemen,

What is the licensor's 'raison d'ètre'?
He has always been the primary guard in securing safe and environmentally sound conduct: at the end of the day, he is responsible.
IPPC and BREF revolve around this person.

However, the licensor has silently been stripped of some of his authorities; that at least is the case in the Netherlands. At best, he can collaborate with other (new) institutes on the pertaining issues.
The common rationale for this is: large-scale transboundary pollution can no longer be adequately addressed by the individual licensor.
With the advent of new instruments, one can observe a decline of the traditional value of BAT ('best available technique').

In the Netherlands we can mention three such instruments:
1. NOx trading,
2. CO2 trading,
3. Energy Efficiency Benchmarking.

All these instruments – either individually or in conjunction (2+3) – are assumed to be equivalent to the IPPC requirement of BAT. Brussels is not convinced and the dispute lingers on.….
A popular belief is that now CO2 trading is in the IPPC, the IPPC allows to discard BAT on efficiency. This can't be true… E- (energy) efficiency is not reserved for CO2 emissions only, but is also good for reduction of other pollutant emissions and for sustaining energy resources.

It is important to make a distinction between E-efficiency and C-efficiency for CO2.
Co-firing biomass or waste is good for C-efficiency, but reduces the E-efficiency; the same can be said about CO2 capture. In these instances optimisation is required.
Better still is to use G-efficiency for green-house gases instead of C-efficiency.
Small example:
High-powered gas-engines with high E-efficiency (42% and up) are now on the market, that apply pre-chamber ignition for very lean gas/air mixtures. The design requires larger tolerances to be maintained which result in high gas (methane) slip, 2,5% and higher, up to 5%, are not uncommon. The gas-engine cogeneration saves some 22% on natural gas use as compared to a combined cycle / boiler combination, thus, 22% less CO2 emission; however, with a gas slip of 5% taken into account, emission in CO2-equivalents is in balance.

Assuming the licensor maintains authority over E-efficiency, how can he deal with it?

The person is usually overworked and swamped in rules, regulations and procedures. The subject is new and extremely difficult.

Does he for instance recognize the picture below?

Or this one?

Or this?

Or this?

Does he appreciate that apart from a good cycle efficiency, one got to minimize many other losses as well to arrive at best total-efficiency?

For instance, referring to coal power plants:
Lower Heating Value: 100%
Available heat after ash-removal, stack and radiation losses: ca. 92%
Cycle efficiency 49% means gross output efficiency of 45%

Deducting for mill, pump, fan, gear and generator losses, a net electric efficiency of say 42,5% may be achieved. Transmission losses: typically 2% points, thus end-use efficiency is 40,5%.
All this already represents a very good performance; most-advanced coal power plants may arrive at ca. 46% net electric efficiency (super-critical steam conditions plus double reheat).
Note: CO2 capture, including 140 bar compression, may have a 10% pt efficiency impact, which is yet likely to be economically sustainable, when applied for Enhanced Oil Recovery (EOR).
Reasonably modern gas turbine combined-cycle plants achieve net (base-load) efficiencies of 52% and higher. Top CC-performance today approaches 60% net efficiency (Baglan Bay, with GE's H-type GT, TIT 1430 °C, P-ratio 23:1), i.e. taking recoverable and unrecoverable degradation into account, a net average efficiency of ca. 58% over the long run.

Modernising and re-powering existing plants for better performance and environmental demands is well-practiced and en-vogue, adding another 20 years to the plant's life. In the late 1980's over 3500 MW plant capacity has been re-powered by gas turbine topping in the Netherlands, resulting in efficiency gains of some 6% pt.

Back to the licensor.
The subject is complex, too complex probably for most licensors. They usually have no background or education in this field. The LCP-BREF, with all due respect, does not give the support the licensor needs to view and tackle shortcomings in efficiency, in particular as regards the revision of permits for existing plants. IPPC requires these plants to adhere to BAT by 2007; the planned horizontal BREF on energy efficiency will likely be a good number of years away from now, which is unfortunate.

The licensor's authority is also limited by the boundaries of the plant facility, he can not make demands to adjacent facilities to interact in efficiency matters.
Small example:
A new large CC- plant is on the verge of being erected, the adjacent facility uses for most of its steam demand an old boiler with a back-pressure steam turbine, fuelled with heavy oil. Due to long-time objections from the part of the licensor, the boiler is now on the list for replacement or refurbishment. The option to take in steam from the power plant could somehow not be effected, thus losing a chance for efficient co-generation. Small solace, a small connecting line is put in place for emergency steam delivery by enabling a duct-burner. (equals only a simple boiler hidden in the flue gas stream)

The licensor needs a fair understanding of power plants, the way these are operated and also the driving forces in a liberalized market. This calls for a special breed of licensors which are not at hand and will probably never be at hand.

Would a system of efficiency benchmarking provide a good means to alleviate the task of the licensor? Such system may require plants to be as efficient as say the top 10% in the world. Seemingly a fair approach. However, energy-efficiency benchmarking is not easy; the process is very tedious, the problems numerous and the results debatable. The simple truth is that energy-efficiencies belong to the best-kept secrets of companies in a competitive market and are thus hard to be extracted. Only a few benchmarking systems have over the years acquired international recognition to some extent, but they are targeted at general operational and managerial information, not at energy-efficiency in particular. Introducing energy benchmarking on a national scale thus provides lots of work to consultants.
To exemplify some problem areas:
As regards organisational aspects:
A non-public expert body may be introduced to facilitate the benchmarking process. This can easily give tensions, at least confusion, as to the issues of responsibility and specific tasks for the licensor and the expert body. Also, transparency of the process and public access to meaningful information can be difficult to ensure.

As regards methodological aspects:
The product slate of the plant and its feedstock may be special or changeable, plant battery-limits uncertain, the facility may comprise various different-type plants raising question as to whether or not averaging efficiencies would be acceptable, how to value various types of energy, how to allocate energy saving by cogeneration (to steam?), should cogeneration be allowed to mask bad process-efficiency, what if just a handful of plants are around the world or limited response is received etc. etc.
As for power plants: it may be questioned whether benchmarking is sensible at all. The whole world certainly is not the right basis, because that is not one level-playing-field. Even regionally, there are big differences in market, resource and infrastructure situation. Plant-size also counts, more so the type of operation, i.e. base-load, medium-load or peak-load. Furthermore, to assemble reliable realistic annual efficiencies will not be easy, if not impossible. Needless to say, that using estimated cycle efficiencies instead would be quite unsatisfactory.
Note: The instrument applied in the Netherlands was supposed to generate CO2 emission reductions commensurate with industry's Kyoto targets, but the first round exercise indicates a lesser result. Examining public reports revealed for a major province that on the average its efficiency in the year 2000 was already at the level of the 'world-top' of 2013.

Thus, is there still hope for the licensor?

Yes, there is. The traditional approach, though a bit stuck into the back of policy maker's minds, provides the best help to the licensor. I am referring to the Environmental Impact Assessment (EIA), stipulated by the EC-directive 85/337. Due to amendments in 1997 and in 2003, this directive has become very strong. An EIA is now required for practically all conceivable major activities, modifications to existing plants included; exemptions can not be made without solid justification; public right to information is well secured, thanks to the Århus convention. Moreover, it is explicitly mentioned what the assessment must entail, refer to Article 3 and Annex IV with footnote. Some highlights: the factor 'climate' must be addressed, long-term effects must be addressed, alternatives must be addressed, envisaged measures must be addressed.
An EIA is inter-alia required for power plant permit-application. Such assessment performed by a knowledgeable consultant provides a good starting point for integral permitting, E & G-efficiency included. It may be assumed that BREFs will positively affect the quality of EIA's. When still in doubt, it would not be unthinkable for a licensor to hire a consultant of his own choice to get a second opinion on certain parts of the EIA. A similar approach could be pursued for periodic license-update (existing EIA may have become out of date also).

Efficiency measures differ from most other emission controls as they generate revenues and not only costs. Therefore, an advisable trade the licensor should master are 'economics', i.e. be able to calculate Internal Rates of Return on Equity (IRQ) and understand how loans can beneficially be used to arrive at high IRQ, while sharing risks in a volatile market. Given present-day mild market interest-rates (ca. 5% on loans), 10-12% IRQ, after tax, is not an uncommon requirement for investment; refer to results below of a simulation on a 400 MW super-critical / super-clean coal-fired power plant, recently built.

400 MW PC-plant Investment 400 mln € Coal-price 25 €/ton [1)]	Price of Electricity [€/MWh]			
	30 [2)]		33	
	pre-tax	post-tax	pre-tax	post-tax
IRQ (100% equity) %	12,3	9,7	14,9	11,7
IRQ (50% equity) %	15,4	12,7	19,6	15,8

1) Due to weakening dollar and oil-price turmoil, the coal-price has skyrocketed over the last eighteen months, up to 50-55 € /ton.
2) PoE to be increased by 2,5% per 10% rise in coal-price to maintain constant IRQ.

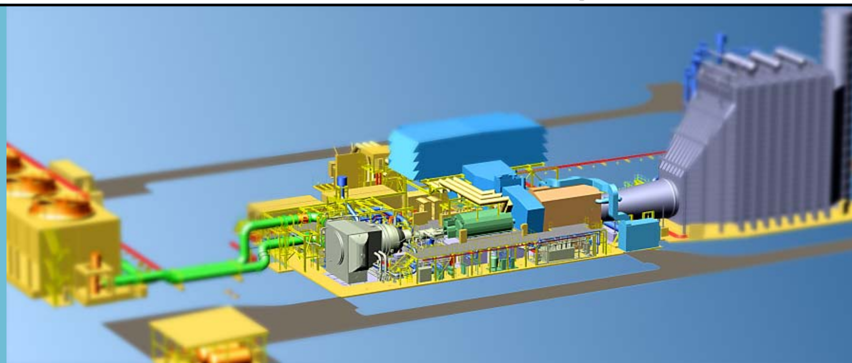
That is my story, thank you for listening.

Gerard Roukens

Plenary session
Producing more with less: Efficiency in Power Generation

MODERN COMBINDES CYCLE POWER PLANTS – IMPROVEMENT OF A HIGH EFFICIENT AND CLEAN TECHNOLOGY

Olaf Kreyenberg, H. Schütz & Heimo Friede
Siemens PG



Modern Combined Cycle Power Plants – Improvement of a high efficient and clean technology

O. Kreyenberg, H. Schütz, H. Friede   Siemens PG

"Energy Efficiency in IPPC-installations"
21 and 22 October 2004
Vienna

Agenda

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- Market Drivers
- Reference Power Plant Product Overview
  - Steam Power Plant
  - Combined Cycle Power Plant
- Reference Power Plant Design Philosophy
- Design Targets
- References

The Market Conditions Have Changed Dramatically in the Power Industry Over the Last 10 Years

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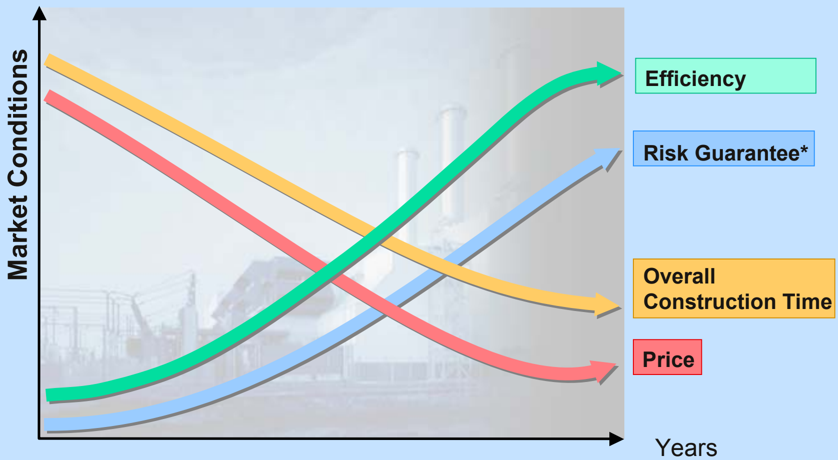

* technical warranties (NOx, et. al.), delivery time

Life Cycle Cost (LCC) Analysis

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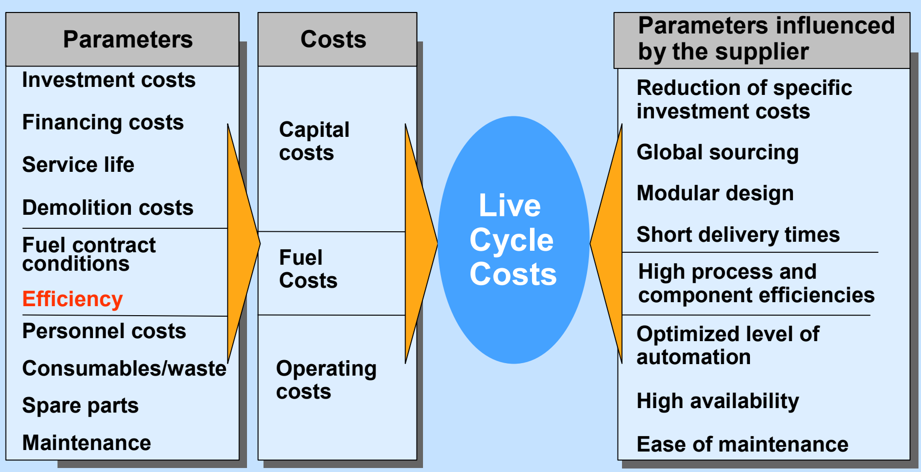

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Reference Power Plant Product Overview

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Our Reference Power Plants are Focused on International Main Market Demand for IPP's

Varioplant

300	300- 450 MW
700	500- 750 MW
900	800- 1000 MW

Customized...

of the shelf...

Components, Islands and Turnkey

Single-Shaft

50 Hz	100, 290, 400 MW
60 Hz	100, 270, 365 MW

Multi-Shaft

50 Hz	200, 580, 800 MW
60 Hz	200, 540, 730 MW

Multi-Shaft Combined Cycle Power Plant
Econopac Arrangement

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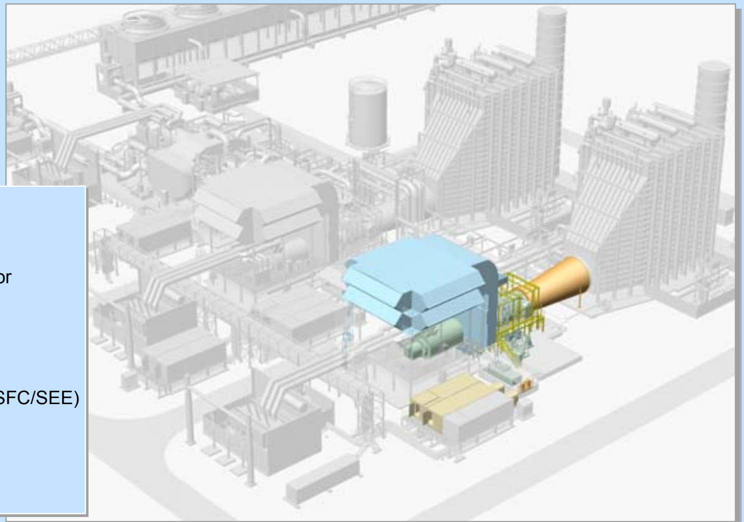

ECONOPAC

- Gas turbine
- Gas turbine generator
- Air intake
- Exhaust gas system
- Fuel system
- Electrical package (SFC/SEE)
- GT - Auxiliaries
- Fire protection
- Options

Multi-Shaft Combined Cycle Power Plant
Power Island Arrangement

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POWER ISLAND

- Econopac
- Steam turbine
- Steam turbine generator incl. SEE
- Heat recovery steam generator
- Major pumps
- Condenser
- Critical valves
- ST - Auxiliaries
- Cycle optimization
- Fuel gas pre-heater
- Options

Multi-Shaft Combined Cycle Power Plant Turnkey (Cooling Tower)

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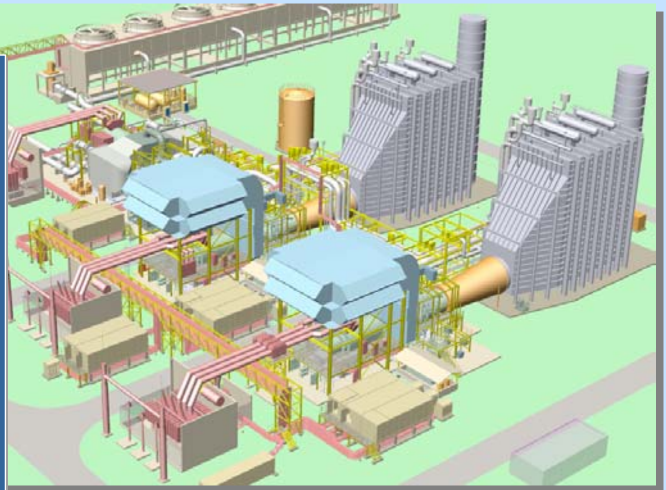
TURNKEY

- Power Island
- Fuel supply systems
- Cooling systems
- Water treatment
- Raw water system
- Waste water system
- Tanks
- Cranes/ hoists
- Buildings/ structures
- Fire protection
- Plant piping/ valves
- Plant electrical
- Further options



Multi-Shaft Combined Cycle Power Plant Turnkey with House (Cooling Tower)

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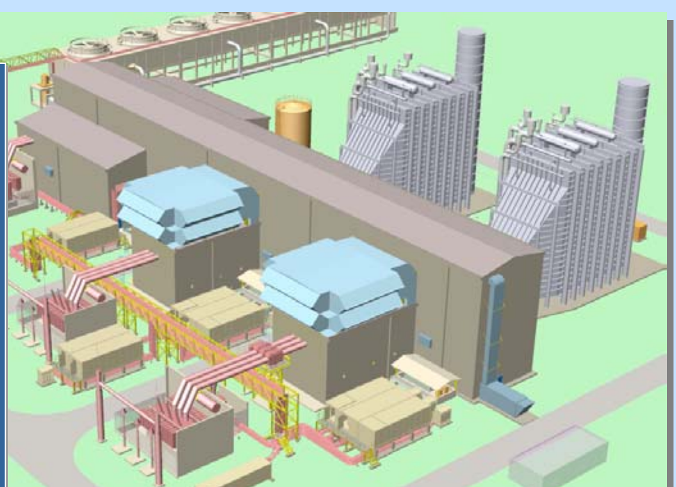
TURNKEY

- Power Island
- Fuel supply systems
- Cooling systems
- Water treatment
- Raw water system
- Waste water system
- Tanks
- Cranes/ hoists
- Buildings/ structures
- Fire protection
- Plant piping/ valves
- Plant electrical
- Further options



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Reference Power Plant Design Philosophy

Evolution of Combined Cycle Power Plant Efficiency

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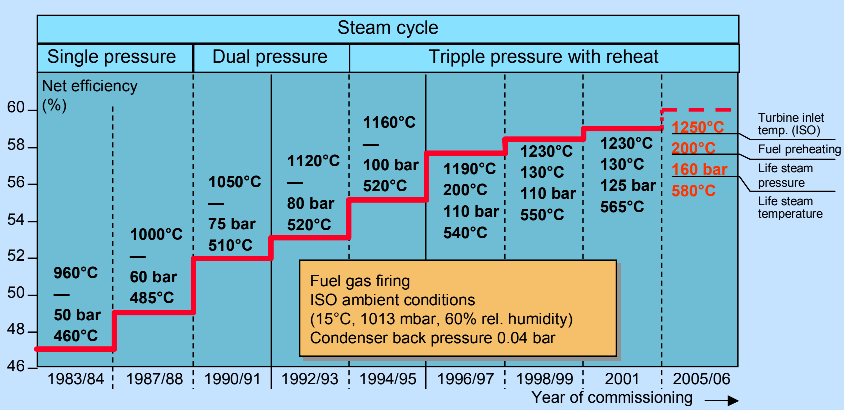

Source: Siemens Gas Turbines

Economical Evaluation Factors

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Evaluation Factors (price related)

(at **12%** targeted **I**nternal **R**ate of **R**eturn for additional investment)

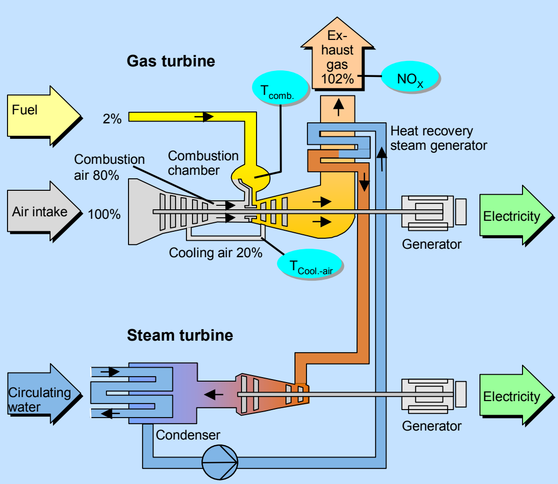
Power Output	0'6 mill € / MW
Efficiency	9'8 mill € / %-point
Lead Time	0'9 mill € / month
Availability	2'6 mill € / %-point

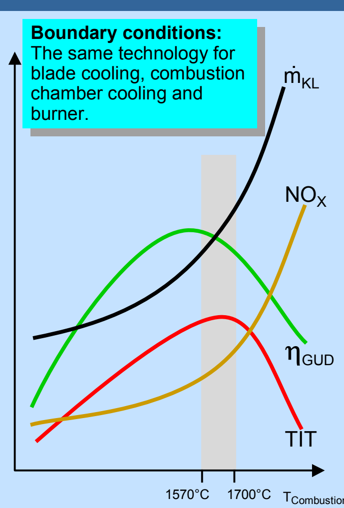
Boundary Conditions

Power Output	397 MW	Lead Time	24 ⇒ 22 months
Efficiency	57.00 %	Overall Project Costs	185 mill €
Load Regime	Base Load (7000hr/a)	Debt/ equity ratio	70 / 30
Electricity Price	37 € / MWh (escalation 1%/a)	Income Tax	35 %
Fuel Price	3.9 € / GJ (escalation 1%/a)	Operating Period	20 years

Power Output, Efficiency, NOx-Emission and Cooling Air Demand versus Combustion Temperature

SIEMENS





Efficiency Improvements due to Increasing the Number of Pressure Stages

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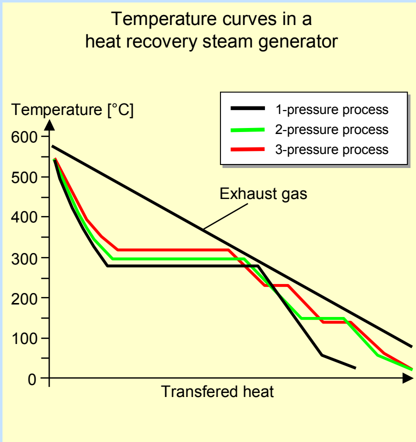

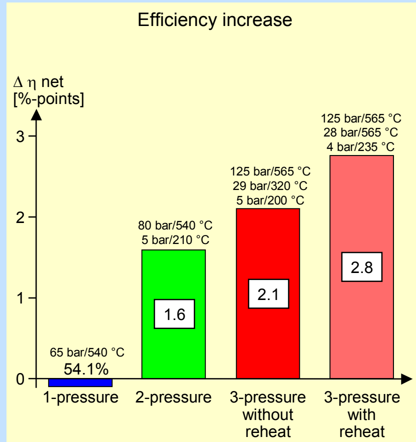

Quick Start up Increases Plant Utilisation Factor...

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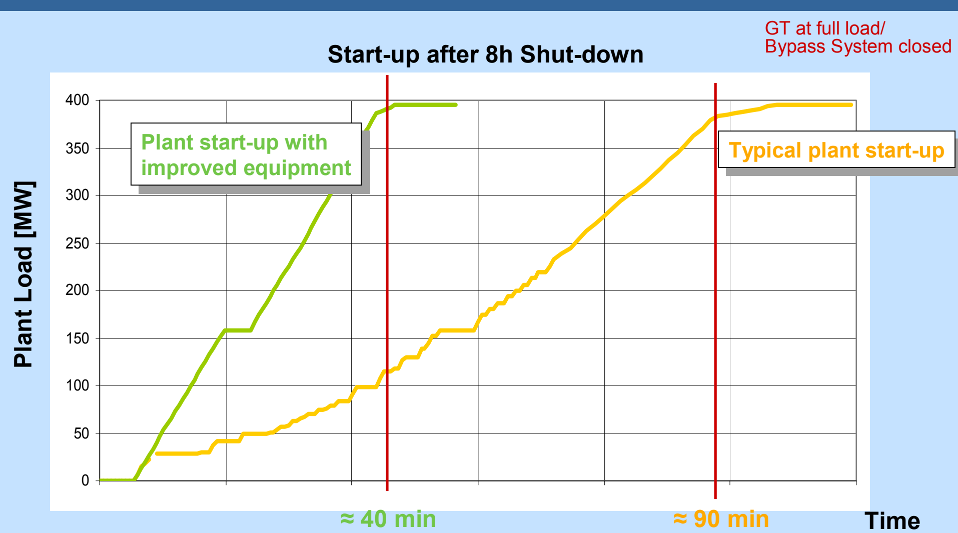

Limiting Values for Flue Gas Emissions

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		World Bank	EU	V94.3A
Gas [1]	NO_x	61 ppm	37 ppm	25 ppm
Fuel Oil No. 2 [2]	NO_x	80 ppm	58 ppm	73 ppm (dry, 1190°C) [3] 58 ppm (dry, 1170°C) [3] 42 ppm (water injection) [3]
Fuel Oil No. 6 [2]	NO_x	146 ppm	97 ppm	not applicable
CO		No restrictions	No restrictions	< 10 ppm
UHC [4]		No restrictions	No restrictions	4 ppm (Fuel Gas) 6 ppm (Fuel Oil)

1) in premix mode at base load and ISO Conditions (at 15 % oxygen in dry exhaust gas)
2) according to ASTM
3) without fuel bound nitrogen
4) Unburned Hydrocarbons

Relationship between turbine inlet temperature and NOx emissions

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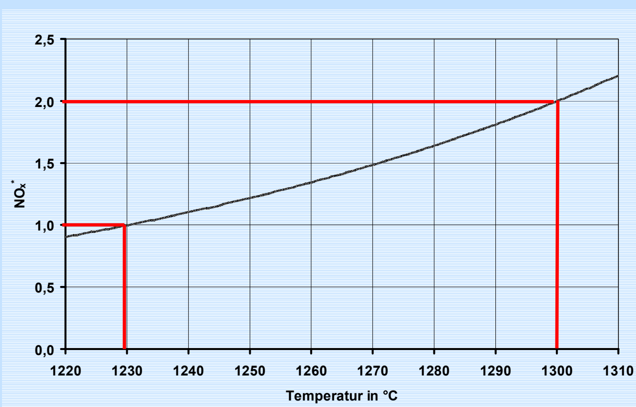

A temperature increase by 70K doubles the NOx- emissions !

SIEMENS

Design Targets

SIEMENS

One the way to the Technical leadership

	now	tomorrow
Efficiency	58%*	> 59%
TIT**	1230°C	1290°C
NOx	25 ppm	9 – 15 ppm

*** depending on cooling conditions**
**** turbine inlet temperature**

Details on additional measures will be presented at a VDI Symposium in Leverkusen 23./24. November 2004

SIEMENS

References

Mainz-Wiesbaden, Germany Combined Cycle Power Plant V94.3A with Steam Extraction

SIEMENS

Mainz - Wiesbaden (Germany)
Concept: Multi Shaft 1+1 V94.3A
Output (nat. gas, site) : 1 x 400 MW
Efficiency (nat. gas, site): >58,4 %*
COD: July 2001
Fuels: Natural Gas (Fuel oil Back up)
Contract: EPC TK plus 10 y. S&M

Pulau Seraya, Singapore: 2 CC 1S.V94.3A
The Most Efficient Plant in SEA

SIEMENS

Pulau Seraya (Singapore)
Concept: Single Shaft 1S.V94.3A
Output (nat. gas, site) : 2x 367 MW
Efficiency (nat. gas, site): >57.2 %
COD: November 2002
Fuels: Natural Gas (Fuel oil Back up)
Contract: EPC TK plus 10 y. S&M

Parallel session
Producing more with less: Efficiency in Power Generation

CO2-REDUCTION TARGETS CALL FOR APPLYING BAT; A NEW 800 MW COMBINED CYCLE POWER PLANT SOUTH OF GRAZ

Josef Tauschitz, Martin Hochfellner
VERBUND-Austrian-Thermal Power GmbH & Co KG

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ABSTRACT

Seeing the problem of increasing electricity demand in Austria combinded with the targets to reduce CO2 emissions and the fact that older power stations will be closed, Verbund has decided to start the project work for a 800MW gas fired combined cycle power plant south of Graz.
The project targets are to realize a power plant according to best available technology.
In the presentation the state of the art of combined cycle power plants will be presented on basis of this new Verbund project. Also the environmental effects of the technology change (partial replacement of existing units by new units using BAT) will be presented.

1 Short description of Austrian Thermal Power / ATP

ATP is a company of the Verbund Group, which operates thermal power plants. In 2003 ATP produced 5,97 TWh electricity, of which 91 % from coal and 9 % from oil. The installed capacity amounts 1901 MW, from this capacity 756 MW are already in cold standby. Because of the closing of a coal mine another 330 MW unit will be transferred to cold standby in 2006. By this the capacity of ATP power stations will be reduced to 850 MW in total. To compensate this reduction in capacity and in order to fulfill the future requirements regarding CO2-reduction, ATP is planning to build a new 800 MW combined cycle plant (CCGT) south of Graz at the site of the existing power plant Mellach.

power station	status of plant	fuel	capacity in operation year 2000 (MW)	capacity in operation year 2008 (MW)
Dürnrohr	operation	coal	405	405
Mellach	operation	coal	246	246
Werndorf 2	operation	oil , gas	164	164
Voitsberg 3	operation 2006 cold stand	lignite	330	
St.Andrä2	cold stand by since 2004	coal, biomass	124	
Korneuburg	cold stand by since 2000	oil , gas	285	
Werndorf 1	cold stand by since 1999	gas	110	
Zeltweg	cold stand by since 2001	coal, biomass	137	
Pernegg	closed	oil	100	
			1901	**815**

Table: ATP Power stations

2 Overall environment for new power plants

The European Energy Market is characterized by the following facts:

- Fully liberalized electricity market
- Reduction of non profitable generating capacity
- Building activity of new generating capacity on a very low level
- Over-aging of existing power stations
- Increasing electricity demand
- Restrictions on the CO2-emissions

These facts will cause the need of new generating capacities by the end of this decade. The realization period of a power plant lies between 5 and 7 years, therefore in case a power plant should be ready in 2010 the process of detailed planning has to be started.

Environment for power plants in Austria

- During the previous decade the electricity consumption in Austria has increased by 2,3 % annually. For the next years an increase of 1,6 % per annum is expected. At the same time a decrease of hydropower electricity production is expected as a consequence of the EU-directive 2000/60/EG (Wasserrahmenrichtlinie).
- The electricity production in Austria has a concentration in the northern part of Austria. The fact that the power stations which were brought to cold standby are located mainly in the South and due to restrictions in the transport capacity of the grid the need of new generating capacity is given specially in the south.
- *Based on 1990 CO2-emissions Austria has to reduce CO2-emission by 13 % until* 2010. Between 1990 and 2002 CO2-emissions have increased app. 10 %. To reach the goal 2010 set by the government the emissions have to be reduced by app. 23 %. The CO2-allocation for ATP for the period 2005 - 2007 amounts 3,3 million tons per year, to compare, the CO2 emission value 2003 was 5 Million tons. Because neither electricity production based on the purchase of C02-certificates nor switching from coal to oil and gas seems not to be profitable at existing electricity price level, CO2-reduction can only be achieved by reduction of generation. Therefore, to keep the production on the existing level, it is necessary to invest in new generating capacities and to use the best available techniques for new plants. The average CO2-emission of ATP power plants amounts at the moment 0,84 tons per MWh, specific emissions of new gas fired combined cycle plants are by the factor 2,3 lower or in other words 0,36 tons per MWh.

3 State of the art of gas turbines and CCGT plants

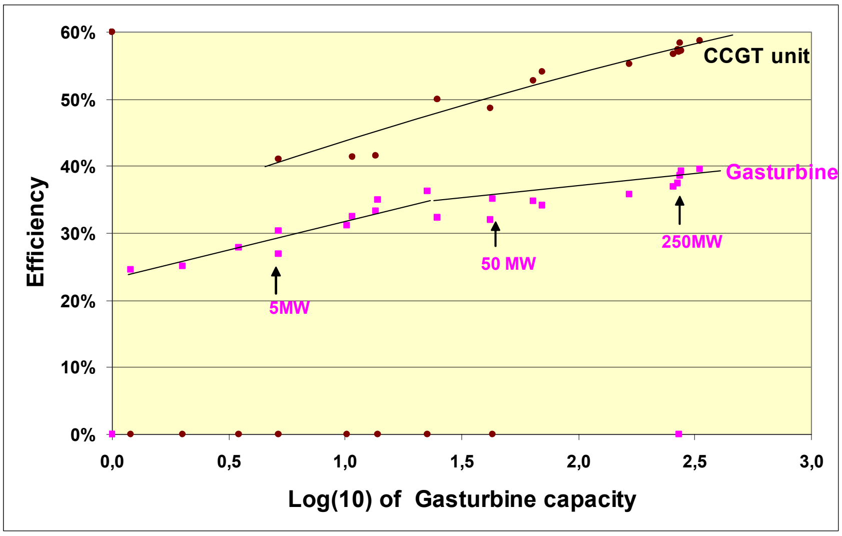
The main component of a CCGT unit is the gas turbine. The development of gas turbines is done by the producers. Planners of power stations normally can only choose between standardized gas turbines from different producers. Also CCGT plants are offered by the producers in standardized packages. This is different to conventional power plants which can be optimized in size and design according to specific needs. In the following the performance of gas turbines and CCGT plants is described from the view of an user and potential buyer, not from the view of a producer.

Efficiency of gas turbines and CCGT plants

The efficiency of CCGT increases with the scale. Reasons for this are:

- Specific losses of small machines are higher than specific losses of big machines
- By economical reasons in small machines complex-high tech solutions are more difficult to realize than in bigger machines
- The need to keep the specific costs for operation and maintenance low, also for small machines, forces to have a more conservative design of these machines

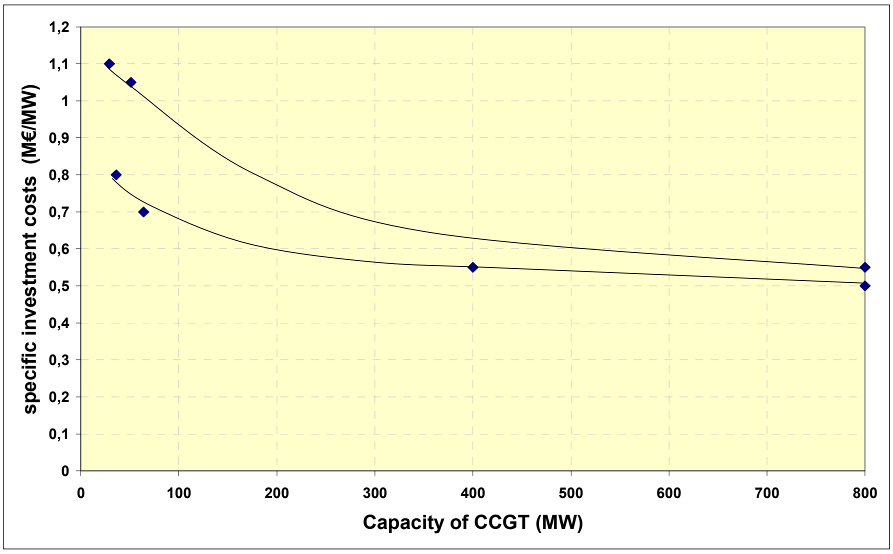
The following graph shows the efficiency of new gas turbines and CCGT units, the operational efficiencies in long time operation are 1 to 2 %-points lower. Big CCGT units (400 MW class), depending on local conditions, are reaching a net-efficiency in the range of 57 % to 59 % while best efficiencies of 30 MW CCGT units are lower than 50 %.



Graph: Efficiency of gas turbines and CCGT units

Specific investment costs of CCGT units

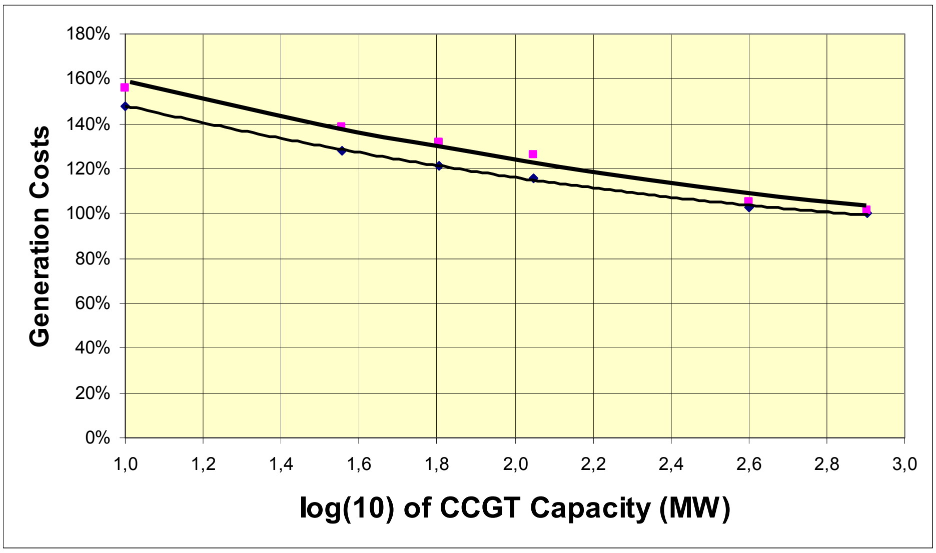
The specific investment costs of CCGT units are decreasing with increasing size, small units have higher specific investment costs than bigger ones. The need to be competitive in the liberalized electricity market forces to choose large unit sizes.



Graph: Specific investment costs of CCGT units

Electricity generation costs of CCGT units

As shown above bigger CCGT units have better efficiencies and lower investment costs. Therefore the electricity generating costs of CCGT plants are decreasing significantly with the scale. The generation costs of a small 10 MW CCGT are 50 % to 60 % higher than those of a 800 MW CCGT. This statement is valid only for CCGT units operating in condensing mode, not for combined heat and power production.



Graph: Relative electricity generation costs of CCGT plants

State of the art of large gas-turbines (250 MW class)

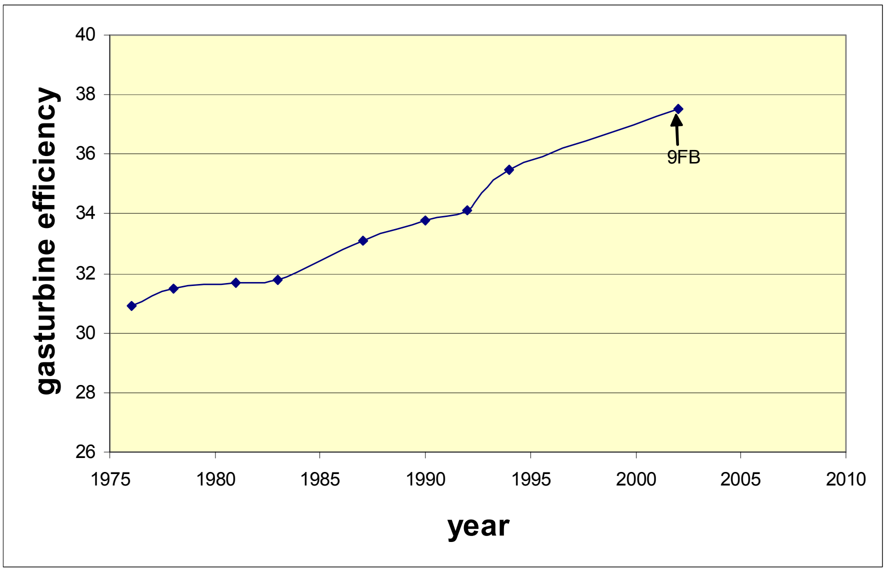
Large gas turbines are offered from four suppliers:
Alstom
General Electric
Siemens
Mitsubishi (at the moment not generally in Europe, not in Austria)

		available gas-turbines				in development / in test	
Producer		Alstom	Siemens	GE	Mitsubishi	GE	Mitsubishi
Type	--	GT 26	V94.3A	GE 9FB	701F3	GE 9H	701H
Gasturbine capacity	MW	274	276	269	270,3		334
Gasturbine exhaust temp.	°C	630	585	622	586		587
CCGT capacity (ISO)	MW	405	407	412	397,7	480	483
GT-efficiency at 100% load	%	Mean value = 38,7					39,5
CCGT-efficiency at 100% load	%	Mean value = 57,9				60	60

Table: Technical data of available gas turbines and CCGT units

The table shows that the capacity of CCGT units from Alstom, General Electric and Siemens are in a narrow range, at ISO conditions between 405 MW and 412 MW. Mitsubishi and General Electric have also gas turbines with 480 MW, the GE machine is still in test condition. It is expected that with these new machines of the 480 MW class a CCGT efficiency of 60 % can be reached. The efficiencies shown in the table are given for new machines and direct cooling. When cooling towers are used for cooling (indirect cooling) the net efficiency of CCGT is app.0,7 %-points lower.

The following graph shows the development of gas turbine efficiency during the last 30 years on example of the GE machine Frame 9 (data were taken from literature). The GE Frame 9 machine is the worldwide most spread gas turbine with high capacity. The graph shows a continuous, nearly linear increase of efficiency since 1975, the extrapolation of this graph shows that in 2010 a gas turbine efficiency of app. 40 % could be state of the art.



Graph: Development of GT-efficiency

The design measures causing the efficiency increase of gas turbines will not be explained in this paper, the main parameters are listed below:

optimized compressors
smaller clearances between rotor and casing to reduce losses
high fireing temperatures

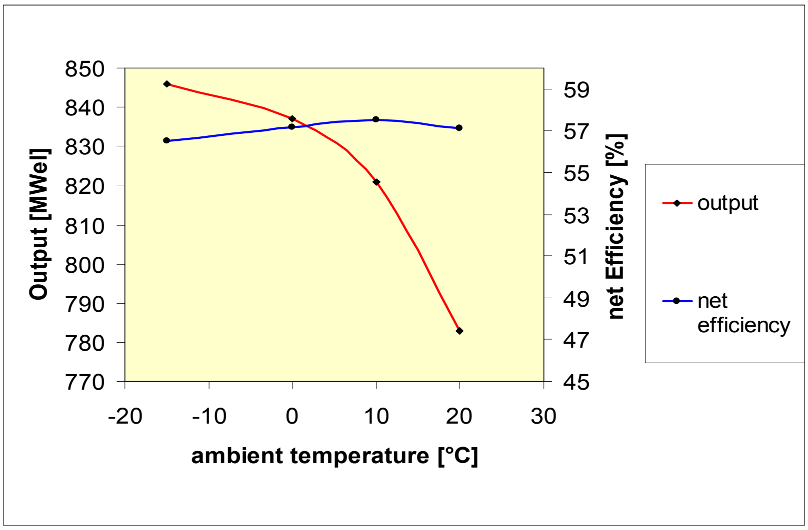
cooling of turbine blades with air
coating of turbine blades
single crystal turbine-blades

Some special features of the manufacturers to increase efficiency are:

- Change axial positioning of turbine runner at continuous operation and start to reduce clearance between rotor and casing — Siemens
- Sequential combustion — Alstom
- Cooling of compressed air — Alstom
- Use of steam instead of air to cool turbine blades — Mitsubishi und GE

<u>Influence of ambient temperature on gas turbine capacity and efficiency</u>

The output of a gas turbine depends on ambient conditions, air pressure and air temperature, the drop of gas turbine output between 0 °C and 30 °C is almost 10 %. The influence of ambient temperature to the efficiency is rather low. In the following graph this dependence is shown (typical example).

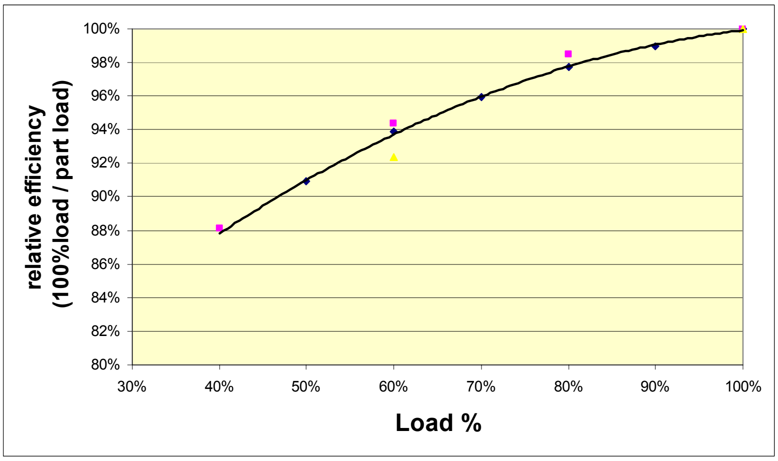


Graph: Typical example for the dependence of GT-output and efficiency

Part load efficiency of CCGT plants

The efficiency of CCGT units at partial load is lower than efficiency at 100 % load.

At 50 % CCGT load the efficiency is app. 10 % lower than at full load (depends on the GT supplier).



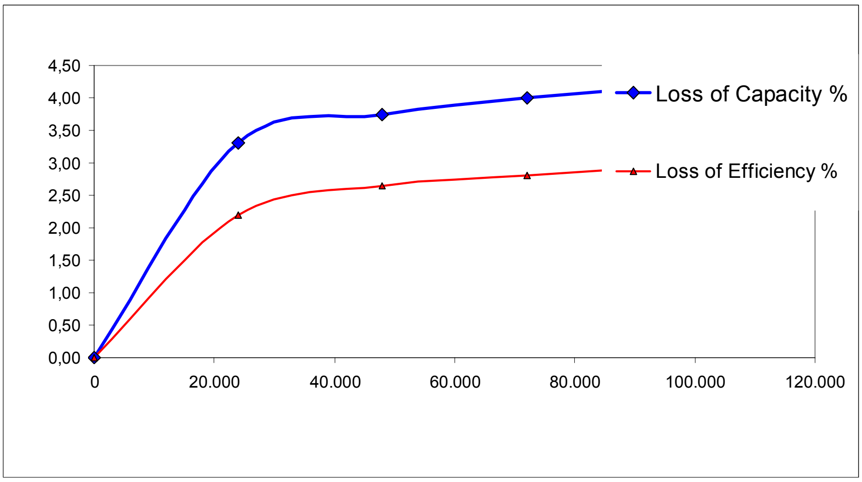
Graph: Influence of load factor to the CCGT efficiency

Though low load factors are no problem for gas turbines the ability of running at low load is limited because of increased NOx-emission values at low load. When emission limit values of LCP directive are applied, CCGT units can be operated between 40 % and 50 % load, when emission limits of Austrians legislation are applied the min load lies in the range of 50 % to
60 %.

Aging of gas turbine output and efficiency

Previous mentioned capacity and efficiency data are data of new plants which are guaranteed by suppliers at the beginning of commercial operation.
During operation the capacity and efficiency are decreasing. Reasons are

- Increase of internal losses
- Coarsening of compressor and turbine blades
- Dirt on the surface of compressor and turbine blades



Graph: Loss of GT-Capacity and -Efficiency during operation

By regular maintenance one part of the capacity and efficiency degradation can be recovered, another part can't be recovered. The graph shows the remaining (non recoverable) part of degradation.

The efficiency loss of the gas turbine leads to higher exhaust temperatures of the gas turbine. Therefore a part of this loss can be compensated in the steam process.

After 30.000 operating hours of a CCGT, the expected efficiency of the CCGT is app. 1,5 % points lower than the guaranteed efficiency of the new plant.

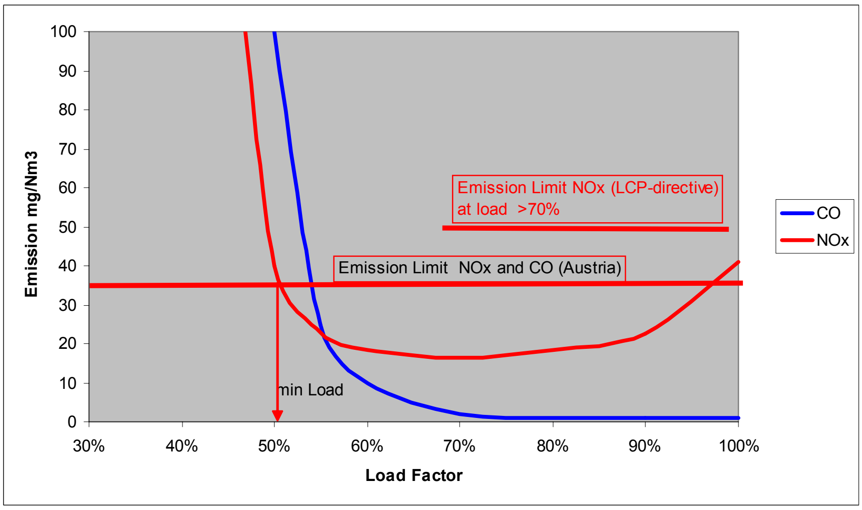
Influence of cooling to CCGT efficiency

The cooling system has an essential influence on the efficiency of the steam process. A decrease of the cooling water temperature by 10 °C improves the CCGT efficiency by app.0,5 %. At typical climatic conditions in Austria for a 400 MW CCGT unit the difference between cooling tower cooling and direct cooling amounts app. 7 MW in capacity, the difference in efficiency is about 0,7 %.

Emissions

Emission limit values according to LCP-directive are:
NOx 50 mg/Nm³ if annual average of CCGT efficiency is lower than 55 %
NOx 75 mg/Nm³ if annual average of CCGT efficiency exceeds 55 %
Taking into consideration the lower part load efficiency of CCGT and the efficiency degradation it seems to be difficult to reach an annual average of efficiency of 55 % with state of the art CCGT units (net efficiency 57 – 59 % in new condition at full load).
Die NOx-limit values are to keep in the load range > 70 % load. No limit if load < 70 %
CO: No limit value in LCP regulation

Austrian regulation stipulates a lower emission limit value for NOx, 35 mg/Nm³, this limit is not dependent on the load factor.
CO: Austrian regulation stipulates max. 35 mg/Nm³ at nominal load (normally 100 % load).



Graph: Typical values of NOx and CO emission depending on the load

The graph shows a typical example of NOx-and CO-emission of a gas turbine (250 MW class).

All suppliers of gas turbines guarantee that the NOx-emission value does not exceed the limit value 50 mg/Nm³ stipulated by the European LCP-regulation. Non of the suppliers guarantees that the NOx-emission does not exceed 35 mg/Nm³. Therefore to keep the Austrian emission limit the installation of a SCR seems to be necessary. The installation of a SCR is technically state of the art, but is worsening the competitiveness of the plant.

A heavy burden is that in Austria NOx limit value must be kept also at low load. The NOx-emission limit value limits the operational load range. By this the possibility of load reduction in off peak hours is limited. This has an enormous negative effect to the economy of a plant, frequent shut downs of the plant during night hours will be the consequence. It is sure that in some cases the higher NOx-emissions during stop and start of the plant will overcompensate the positive environmental effect of low NOx-emission limits. So the total environmental effect of the low Austrian emission limit at low load could be negative.

In a common liberalized electricity market different emission limit values in European countries are disturbing competition and will boost the intentions to build power stations in neighbor countries having less strengthened environmental limits.

4 The 800 MW CCGT project „Mellach"

In the period 2000 to 2006 ATP intends to convert a capacity of app. 1200 MW (6 power stations) from operational to cold stand by status. Due to future restrictions of CO2-emissions it is intended to substitute this generation capacity with modern CCGT units according to the state of the art.

Preliminary studies of ATP have shown that highest efficiency and lowest investment costs can only be reached with CCGT units in the range > 400 MW. Furthermore the investigation has shown that a 800 MW unit consisting of two widely independent 400 MW units with common infrastructure at one site would be the best solution for ATP.

a) Selection of site

At the beginning of the investigation in total five different sites were investigated, this investigation has shown that Mellach site would be the most preferable site for a CCGT.

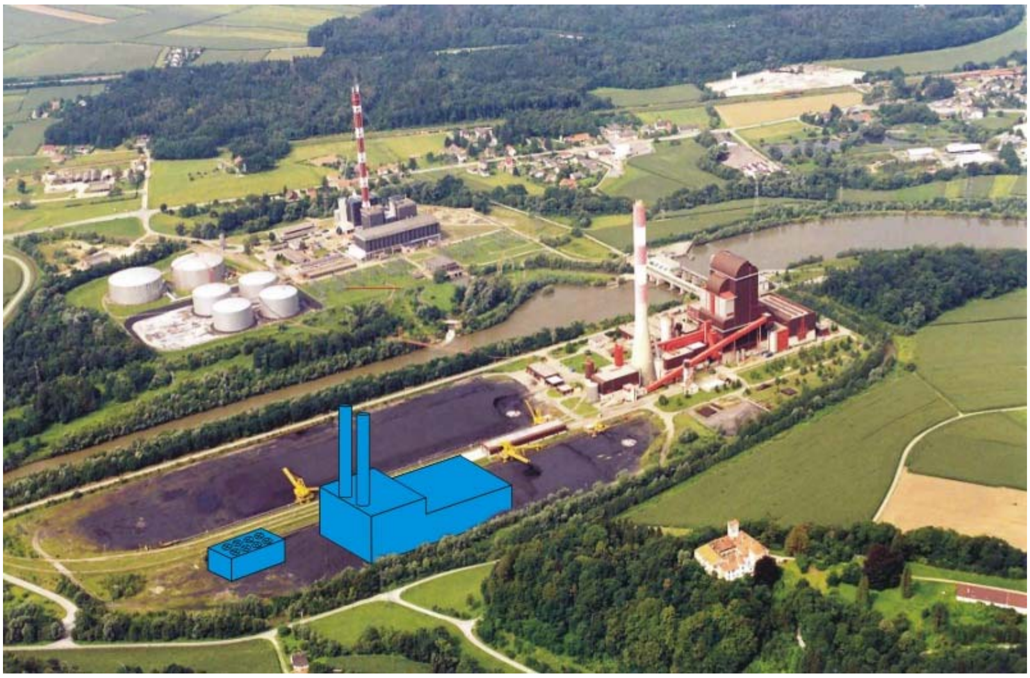
The evaluation criteria which have led to the decision of Mellach have been

- Situation of the grid (capacity demand is especially given in the south of Austria)
- Grid connection
- Gas supply (supply lines)
- Cooling water
- Possibility to supply district heat
- Personal and infrastructure synergies with existing industries (power stations)

b) Positioning of the CCGT at the site of the coal power plant Mellach

The CCGT unit will be erected on the eastern part of the coal yard of Mellach power plant (Mellach is hard coal fired, nominal capacity 246 MWel). The remaining coal yard is sufficient for future operation of the plant.

The vicinity of the new CCGT to the existing plant will enable to have a common use of infrastructure and personnel (common management, common workshops and stores, common ammonia storage, common water treatment …).



c) Supply of district heat to the city of Graz

From the power stations Werndorf 2 (164 MW, oil fired) and Mellach (246 MW, coal fired) in total app. 800 GWh/a, max. 250 MW district heat is supplied to the city of Graz. In future when the CCGT is in operation, it is not intended to use Werndorf plant for base load in winter time. The district heat supply from Werndorf plant will be substituted with district heat from the CCGT plant.

To have a redundancy in district heat supply the new CCGT will have the ability to supply min. 250 MW district heat (this is 100 % of existing supply).

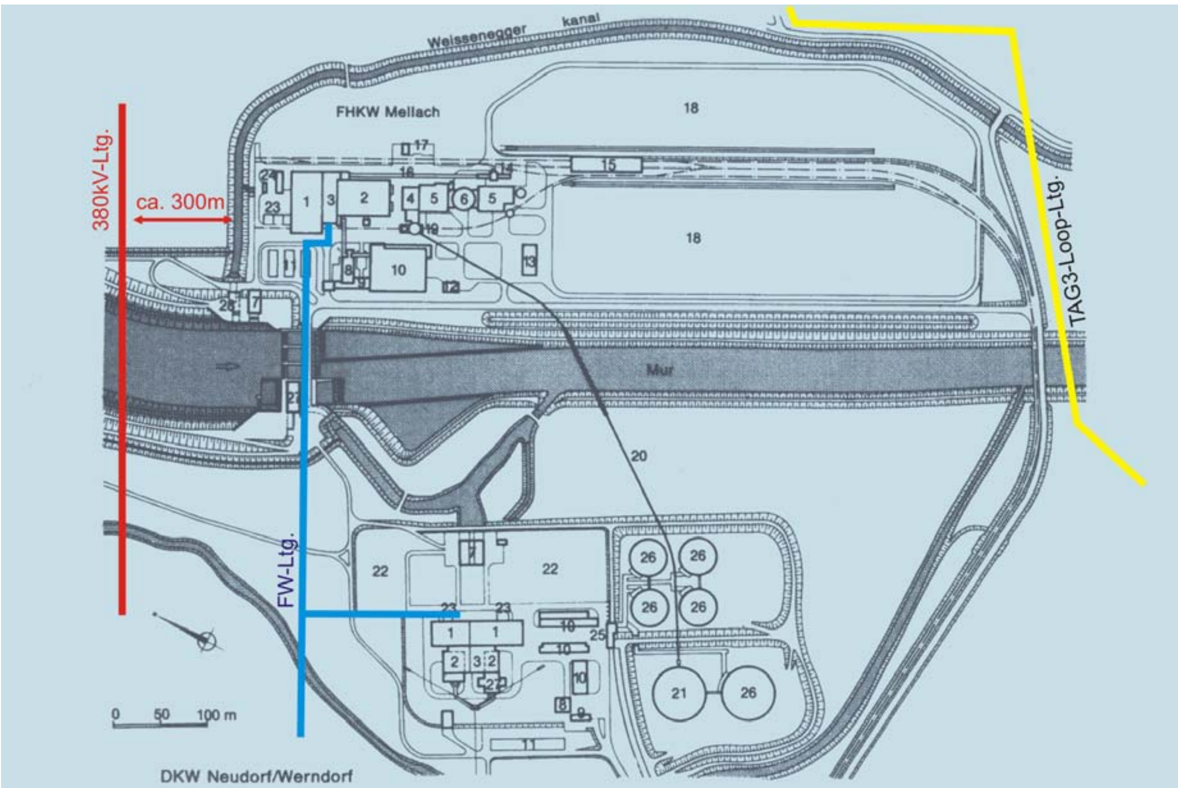
Net capacity of CCGT	800 MW
capability of district heat supply	250 MW
Net efficiency in condensing mode	58%
Net efficiency when supplying 250MW of distric heat	70%

Table: Technical data of CCGT

d) Gas supply and grid connection

The Trans-Austria-Gaspipeline (TAG), the main connection from Russia to Italy is routed directly along the power station area, also the main tapping point of Styrian gas network to the TAL pipeline is situated very near to the power station. Therefore the gas connection line to the CCGT will be very short.

The connection point to the grid will be the grid substation Zwaring in app. 5 km distance to the plant. If the new planned 380 kV transmission line from Rothenturm to Zwaring will be realized in time the CCGT will be connected directly to this new 380 kV line.



e) Emissions

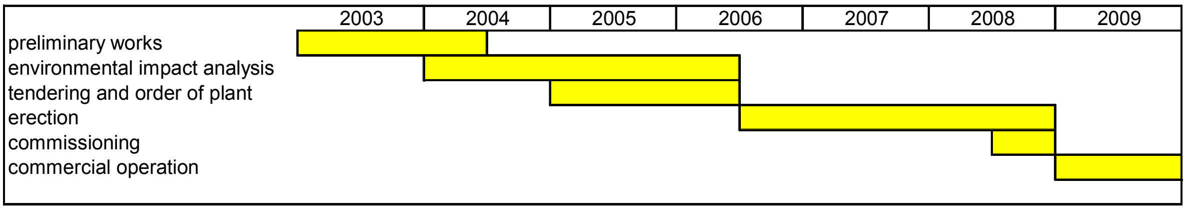
The emission limits according Austrian regulations for the CCGT are:
NOx 35 mg/Nm³
CO 35 mg/Nm³ (at nominal load)
Dust 5 mg/Nm³

The new CCGT unit will be able to keep this emission limits, to keep the NOx-limit a SCR unit will be installed. The expected operational NOx-value is 20 mg/Nm³.

The specific CO_2-emission of the new plant will be 0,36 to/MWh.

f) Project time table

Preliminary project investigations were done early 2003, at the moment the basic planning and environmental impact analysis are in work. It is planned to submit the project to the authority for approval beginning of next year. If approval is reached end of 2005 commissioning of the plant could commence mid 2008.



Parallel session
Producing more with less: Efficiency in Power Generation

EFFICIENT ENERGY SUPPLY (ELECTRICITY AND DISTRICT HEAT) FOR THE CITY OF LINZ

Johann Gimmelsberger
Linz Strom GmbH

EFFICIENT ENERGY SUPPLY (ELECTRICITY AND DISTRICT HEAT) FOR THE CITY OF LINZ

Johann Gimmelsberger, *Linz Strom GmbH*

History

Linz Strom GmbH is a company belonging to the Linz AG. The Linz AG is the leading multi utilities company in Upper Austria. In 1970 two power station units were put into operation to form "Linz Mitte – power station". At this time this was a pioneer in combined heat and power application for district heating. The fuels utilized were coal and heavy fuel oil. Environmental protection measures imposed by the City of Linz lead to the addition of flue gas desulphurisation in 1990. These stringent protection measures imposed on the City of Linz meant that domestic fuels were substituted by district heating and consequently the demand rose from 80 MW to 275 MW within 20 years.
A big step forward was gained in 1993 with the start up of power station "Linz Süd". Where two GE Frame 6 DLN gas turbines, two heat recovery steam generators (HRSG) and an extraction condensing turbine were installed.
In 1997 a peak shaving gas turbine GE frame 6 was installed. In 2001 the upgrading of the open cycle gas turbine with HRSG and the back pressure steam turbine was made necessary by the liberalisation of the electricity market and the steady growth of district heating demand.

Modernisation

The premisses behind the modernisation of "Linz Mitte – power station" proved to be very difficult.
The electricity market became more complex and less predictable. Long term agreements and capcity prices were replaced by base / peak prices, spot market etc. and the price of electricity droped due to huge excess capacities in the European power market.
The numerouse discussions about the greenhouse effect, climatic change and fossil fuels did not in general facilitate the decision process.
The final decision was that the modernised power station ought to achieve high efficiency, a high power to heat ratio, high fuel utilisation and also promote sustainable development.

District heating systems in general suffer from low full load operating hours and great load differences during the day and from season to season. The volatility of power prices and the necessity to produce heating power according to weather conditions and the problem of predicting both stiffened the requirements.
To overcome these barriers different systems were evaluated: different sized gas turbines with and without supplementary firing, gas turbines with heat recovery boilers and heat recovery steam generators, extraction/condensing turbines as opposed to backpressure turbines, peak load boilers and hot water storage tanks to accumulate energy.

Feasibility studies showed the advantage of the system: a gas turbine with high electric efficiency, a two pressure heat recovery steam generator, an extraction backpressure steam turbine with the heating up of district heating water in progressive stages and a hot water storage tank.

The gas turbine was made by GE, the HRSG came from Alstom Brno and the steam turbine was provided by Siemens Görlitz. The general contractor was VA Tech Hydro.

Hot Water Storage Tank

The hot water storage tank measures 65m in height and 26m in diameter with a volume of 34.500 m^3 . The tank is operated at atmospheric pressure with a "steam cushion" on top to prevent the ingress of air.
The tank is made from boiler plating and was welded on site.
500mm of insulation with a thermal conductivity coefficient of less than 0.05 W/m^2K reduces the heat loss to a minimum.
The span between the feed temperature (97°C) and the return temperature of district heating water (57°C to 60°C) results in a maximum capacity of approximately 1300 MWh.
The physical principle behind the storage tank is quite simple. Hot water is fed in at the top of the tank at very low speed and is withdrawn at the bottom when it is charged and the whole process is reversed when discharged. (see figure 1). The know-how of design and construction is from Dr. Anders Hedbäck (S), who has designed several storage tanks through out the world. VAM Anlagentechnik und Montage were responsible for construction.

Operation of the Storage Tank

The storage tank is designed for weekly operation. This means, that the tank is charged and discharged within one week depending on the excess heat from power production and the heat demand from the district heating system.

In winter the tank is charged during the night (10.00 pm to 6.00 am) and discharged during the day.
In summer energy is stored during the week and is used at weekends. (see figure 2) In spring and in autumn, the operation depends on power prices and the heat demand. At these times the most important feature of the accumulator is that the morning district heating peak demand is shaved. No peak load boilers are required. During the day the power production units can be operated at constant load and excess heat is stored in the accumulator.
This leads to the nearly autonomous supply of electricity and heat.

The benefits of the heat storage tank are the reduced operation of peak load boilers, higher fuel utilisation as compared to condensing extraction turbines, and consequently fuel and CO2 savings. The stored energy can be used as back up energy and contributes to ensuring supply.

Biomass Power Plant

The conditions behind the biomass power plant are different to those of the combined cycle power plant.
First of all the power to heat ratio of the biomass power plant is much smaller. Heat production is the main product and electricity is a kind of a by-product.
On the other hand, the production of electricity determines the economic benefit (promotion of green / renewable electricity).
The fuel market (wood, residues from the timber industry and from forestry) is not as developed as the fossil fuel market. The building of a big power plant could affect the market in a way that is not beneficial to the project. The transport of biomass is more complex than natural gas and has an effect on both ecology and economy.
The specific price of the technology required for the generation of electricity is quite high when compared to that of combined cycle technology.

Our objective was to design a biomass power plant with maximum fuel utilisation, high electricity output with innovative and reliable technology.
Therefore the significant dimension behind the design was the load duration curve of the district heating system.
The technology used is a biomass fired Rankine cycle with a backpressure extraction turbine. The steam extracted is used internally in the power plant. The exhaust steam is condensed at 0.8 bara to provide district heating water with a temperature of 80°C and high electricity output.

The Data

Thermal Input	35 MW
Electrical Output	8 MW
District Heating Output	22 MW

Technology

The fuel is fed into the boiler on a wandering grate via a spread stoker. There is high turbulency on the grate caused by blowing half the combustion air through the grate. The high turbulence encourages very effective combustion, so that the air to fuel ratio can be very low. The secondary air and recirculated flue gas is blown in at the front and at the back of the combustion chamber. The combustion chamber consists of finned walls like the flue gas passes. The boiler is equipped with 3 superheaters and economizers for combustion air and feedwater.
Aalborg Energie Technik (DK) is responsible for the engineering and construction of the power plant.

The fuel biomass will provide 15 to 17% of the heating energy of the district heating system of Linz. This is a significant contribution to achieving Upper Austria´s targets in renewable energy utilisation. For Linz Strom the biomass contributes towards securing supply and fuel diversity.

Conclusion

To achieve a sustainable energy supply it is obligatory to invest in up-to-date technology. But this is not sufficient. The technology used has to perfectly fit into the energy system.
Clean production, high efficiency (in a technical as well as an economical sense) and security of supply are key-factors in this business. We are convinced that we can meet these requirements with our modernized power station “Linz Mitte”:

- Combined cycle power unit
- Biomass fired power unit
- Heat accumulator

The modernized power plant is designed for maximum fuel utilisation. This causes constraints but flexibility is regained by the heat accumulator. So what we actualy operate is an electricity orientated heat-focused set up.

Heat storage tank

Plenary session
Producing more with less: Efficiency in Power Generation

"THE FLAMELESS OXIDATION MODE": AN EFFICIENT COMBUSTION DEVICE LEADING ALSO TO VERY LOW NOX EMISSION LEVELS

Franck Delacroix
ADEME (French Agency for energy and environment management) 2, square La Fayette, BP 406, 49004 Angers, France. E-mail : Franck.delacroix@ademe.fr

"THE FLAMELESS OXIDATION MODE": AN EFFICIENT COMBUSTION DEVICE LEADING ALSO TO VERY LOW NOX EMISSION LEVELS

Franck DELACROIX, *ADEME (French Agency for energy and environment management)*

ABSTRACT

A lot of current European industrial furnaces use natural or other types of gas as fuel. Important work has been completed mainly in Japan and United States to design new types of burners able to use high temperature air while reducing at the same time the NOx emission level and improving the furnace temperature homogeneity.
Several manufacturers propose now this new type of burners but a lot of references in Europe remain of a quite small size.
This is why ADEME has sponsored a three year project gathering IRSID/ARCELOR, Stein Heurtey and Gaz de France in order to better characterise this combustion mode and work on new design tools necessary to promote the diffusion of this technique at higher scale.
The purpose of the presentation will thus be to describe the principle of this new combustion mode, the advantages concerning NOx and CO_2 emissions and productivity, some results of this program and application apportunities in the different industrial sectors.

1. FRAMEWORK

Until the recent years, gaining energy efficiency in process furnaces and reducing NOx emisssion levels at the burner level was often far to be compatible.

One mean to increase the energy efficiency of a given combustion device was to preheat the combustion air.

The possible indicative influence on NOx emissions is reported in the table 1 below (reference 1).

Table 1

Air preheat temperature (°C)	NOx (mg/Nm^3 – O_2 3% - dry gases)
100 – 200	Below 400
300	Up to 450
400	Up to 600
500	Up to 800
700	Up to 1500
800	Up to 2300
900	Up to 3500
1000	Up to 5300

This phenomenon may be easily explained considering the main NO formation route (the thermal one) among the three possibilities (fuel, prompt and thermal NO formation).

This NO formation route as been described by Zeldovitch in the following way :

Thus, the concentration of NOx from first generation designs of regenerative burners are known to be such that they may significantly exceed the 'achievable release levels' defined by several environmental organizations.

For more than ten years now, important studies have been realized in Japan, Germany, and USA to develop new types of burners operating with high temperature combustion air

(over 1000 °C) while not only reducing NOx emissions, but also increasing the furnace temperature uniformity (by suppressing hot spots).

Today, several manufacturers have commercialised this type of burners.

Industrial demonstrations have been mainly validated in Asia (slab, billet or reheating furnaces, etc). This new type of burners operate in the « flameless oxidation » mode.

In Europe, the first demonstration appeared several years ago. However these operations remain small-scale demonstrations.

More extensive utilization of these techniques on industrial scale installations will only be possible if reliable prediction tools are available to study the different options to modify existing or develop new furnaces.

A project was therefore initiated by Gaz de France in partnership with IRSID (Research and Development Division of ARCELOR) and Stein-Heurtey (furnace designer) and a funding support of ADEME (French agency for energy and environment management), to evaluate the capabilities of the HiTAC (High Temperature Air Combustion) technology.

The three years project began in October 2000 and was composed of the three following phases :

- basic understanding of this combustion mode, especially through semi-industrial test rigs,
- development of modelisation tools to be able to assess the furnace behaviour (CFD, global tools),
- the preparation of a demonstration project at industrial scale.

2. THE FLAMELESS OXIDATION MODE

2.1 The Principle

In "flameless oxidation" mode, the feeding of oxidising air and fuel gas is performed separately (extreme staging of combustion) with high injection speeds.

The geometry of the burner and of the combustion chamber, as well as the high speeds of the flows, create large internal recirculations of the combustion products to the burner (see figure 1). The high temperature of the recirculated combustion products (> 1000°C) is used to initiate and maintain this mode of "combustion". The flame can then no longer be seen and combustion is, for the most part, distributed throughout the volume of the combustion chamber.

This is why this combustion mode is called the flameless combustion mode.

The relative homogeneity in temperature and in composition of the combustion chamber is a notable characteristic of the process.

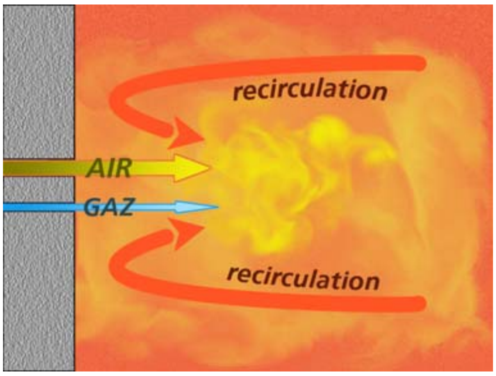


Figure 1 : The principle of flameless oxidation mode

Figure 2 : Principle of a process integrating the flameless combustion mode

Even if this combustion mode has not yet any precise definition, some experts of this field have tried to set up some indicative rules to characterize this combustion mode.
Figure 3 illustrates this attempt.

Figure 3 : An attempt to characterize the flameless combustion mode

2.2 The advantages : NOx emissions, heat transfer optimization and noise level

The flameless oxidation mode allows a large reduction of NO_x emissions by (see § 2.3.1 characterisation) :

- locally reducing the concentration in oxygen - the high internal recirculation leads to a significant dilution of the air by the combustion products before the reaction. The local volumetric concentration of O_2 can achieve values of between 3 and 15%.
- avoiding peaks of temperature.

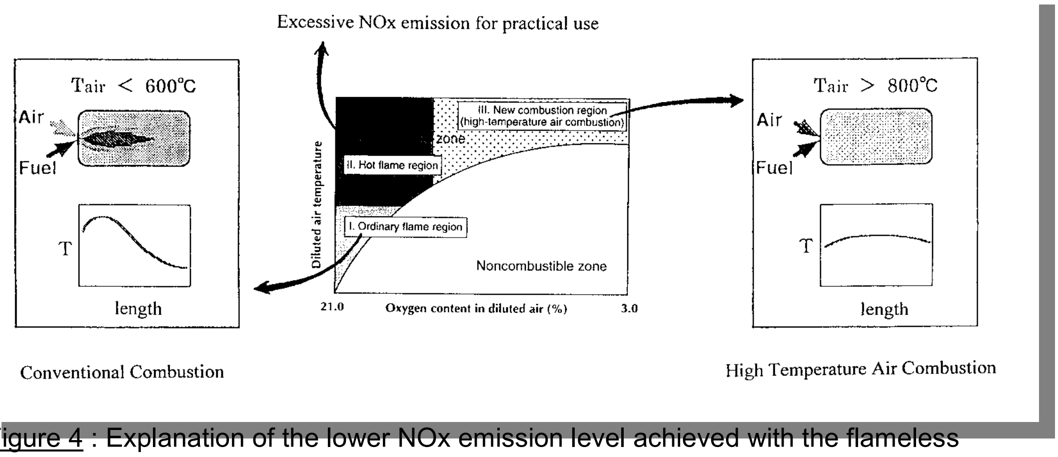


Figure 4 : Explanation of the lower NOx emission level achieved with the flameless combustion mode in comparison with conventional combustion

Actually, in conventional systems, such pre-heating of the air leads to very high local temperatures in the flame, and therefore to high NO_x emissions. The temperature profile induced by a flameless-type combustion is relatively flat. The emissions of nitrogen oxides (formed by the thermal mechanism), greatly influenced by the local temperature in the flame, are thus very greatly reduced and the homogeneity of the temperature in the enclosure is improved. As a result of the reduction of temperature peaks in the flame, the mean temperature level of the furnace zone can be increased, without leading to local overheating in the vicinity of the burners. The heat transfer to the product can thus be considerably increased. In addition, the noise level induced by the combustion is greatly reduced.

2.3 STUDY OF THE HEATING EQUIPMENT

This was one of the “core” tasks of the project.

An heating equipment operating in accordance with the principle of the flameless oxidation mode has been fully characterized.

The burner used during the study is the HRS-DL burner from the NFK company (see figure 5). This is a honeycomb regenerative burner which operates in pairs.

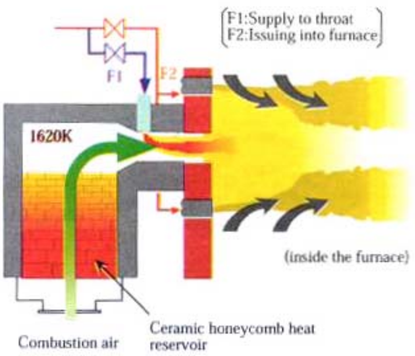


Figure 5 : HRS-DL Burner From the NFK Company (Japan)

2.3.1 Characterisation

The energy and environmental performances of the burner have been assessed by input/output measurements and compared to burners of the same technology tested previously by Gaz de France (see figure 6).

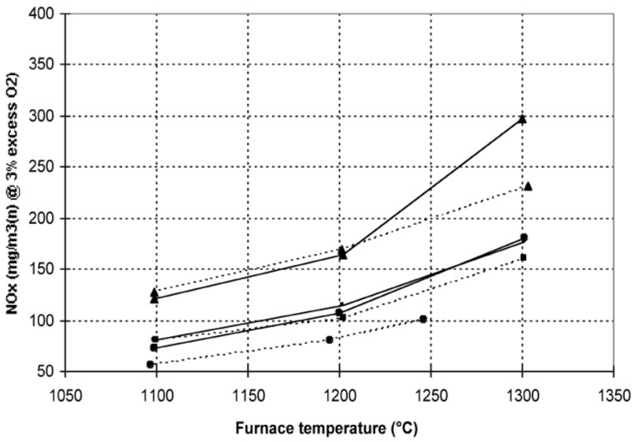


Figure 6 : NOx emissions from burners operating in the flameless oxidation mode, as a function of temperature

The “flameless oxidation” technique employed on this burner is used to ensure low levels of NO_x emission (the tests have shown that the emissions from this burner are always less than 300 mg/m3(n) at 3% of O_2), even with high pre-heated air or high furnace temperatures. The use of refractory material with a honeycomb structure as thermal capacity displays high performance with great flexibility of use.

In general, no operational problems have been observed on the burner. These tests, conducted in dynamic mode, have enabled to isolate the various operating parameters of the burner, independently of each other, as a result of the great flexibility of the test cell used at the Research Division of Gaz de France.

In particular, the influence of the main operating parameters of this regenerative burner have been highlighted :

- the increase in the NO_x emissions and the reduction of the energy efficiency of the equipment with the increase in the temperature of the test cell,
- the non-negligible effect of the air fuel ratio and the furnace temperature on the nitrogen oxides emissions,
- the weak influence of the thermal input on the NO_x emissions as well as on the combustion efficiency,
- the strong influence of the percentage of exhaust gases through the burner on the combustion efficiency, and its slight impact on the NO_x emissions,
- the influence of the switching time on the NO_x emissions, with an optimum at 30 seconds regarding the energy efficiency for this particular burner.

2.3.2 Detailed measurements in the Flame

In the context of a thesis with the CORIA (Research institute located in Rouen), detailed measurements (temperature, velocity, species, radiation, etc.) in the flame in stationary mode have been conducted. These experimental data have been used not only toward a better knowledge of the physical/chemical characteristics of this flame but also as data for validation of the numerical simulation of the burner.

The burner used is extrapolated from the NFK burner characterised in the context of the project. It is composed of a central airflow surrounded by two injections of natural gas. It is installed in a furnace which is instrumented to allow measurements to be taken for overall characterisation of the combustion regime, and detailed measurements in the flame (see figure 7). Several test cases have been studied around the reference point corresponding to operation closest to the actual conditions.

- thermal input = 200 kW,
- air fuel ratio = 1.1,
- preheated air temperature = 1000°C,
- furnace temperature = 1300°C.

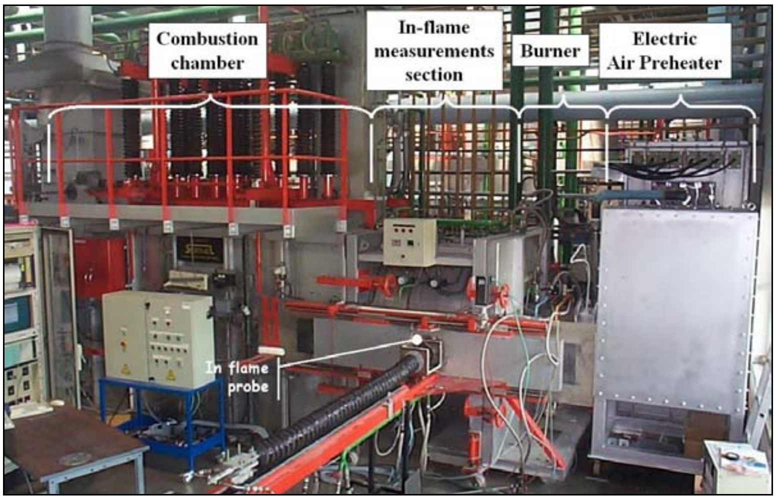


Figure 7 : Test installation at semi-industrial scale

In operation, the detailed measurements conducted were as follows:

- visualisation of the reaction zone by OH* chemiluminescence emission imagery (see figure 8a),
- temperature field by fine-wire thermocouple (see figures 8b and 9),
- velocity field by Laser Doppler Velocimetry,
- concentration fields of stable species (CH_4, O_2, CO, CO_2 and NO_x) by sonic nozzle probe.

For instance, figure 8-b presents the mean local concentration in CO and the mean local temperature. From the measurements of concentration in carbon monoxide, it is possible to determine two distinct reaction zones:

- a primary zone which is highlighted by a region of concentration in carbon monoxide greater than 1% of the output of the burner and of low radial thickness.
- a secondary reaction zone located downstream of the primary zone and more extended radially.

This sudden radial expansion of the CO concentration corresponds to the start of the merge zone of the jets of gas and air at X = 200 mm, obtained by velocity measurements. The secondary reaction zone is located in the two mixing layers between the air jet and the two gas jets, as confirmed by the average chemiluminescence image on the OH* radical, created by the optical access at the bottom of the chamber (figure 8a).

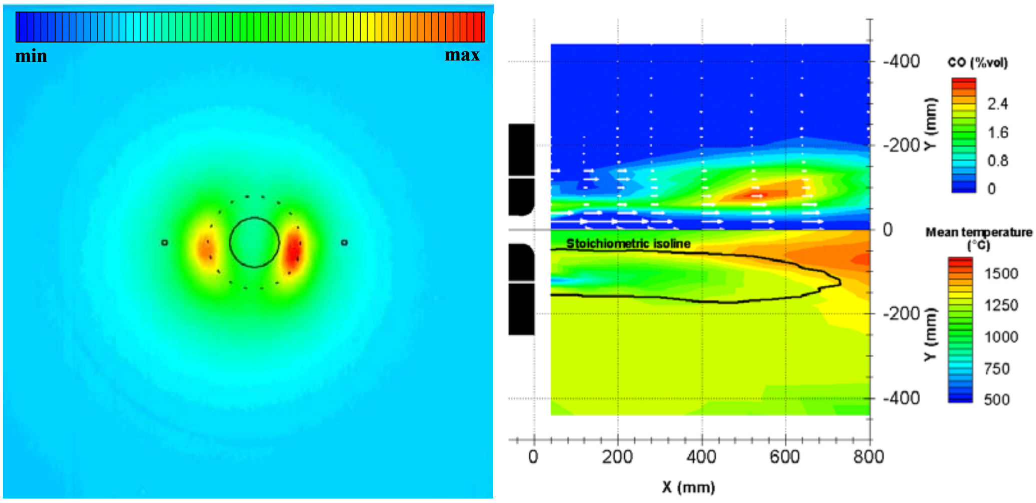


Figure 8 : (a) Chemiluminescence Emission of the OH* radical – (b) Concentration in CO and mean temperature

In figure 9, the results of the mean temperature measurements obtained in the flame are also presented. It is possible to see that the temperature gradients are low and that the maximum is less than 1550°C, which is the threshold temperature for the nitrogen oxides formation by the thermal mechanism. In the recirculation zones, the temperature is homogeneous and of the order of the temperature application (1300°C). If it is looked at the evolution of the temperature fluctuations, two zones can been observed, located between the flow of air and the two injections of gas, where the fluctuations reach values of the order of 10% at most. Beyond this, they are very weak, and this is one of the remarkable characteristics of this combustion mode too.

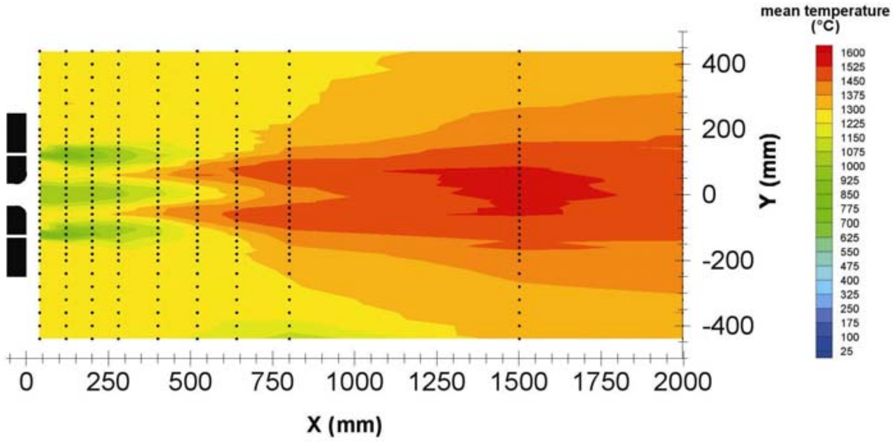


Figure 9 : Fields of the mean temperatures obtained in the flame

These measurements enable to study the mechanisms which drive this combustion regime, both in the conditions of flame stabilisation and for quantification of the recirculation rate of the combustion products.

They have also fed the discussion on methods to simplify the representation/simulation of this type of burner at an acceptable cost (low computing time).

This is the subject of next paragraph.

3. THE SIMULATION OF THE FLAMELESS OXIDATION MODE

3.1 Pre-dimensionning of slab reheating furnaces

An existing software has been adapted by the Polytechnic Faculty of Mons and IRSID to simulate the installation of burners working in the flameless combustion mode into any area of a furnace.

Considering the stationary regime, this tool showed that :

- a decrease in fuel consumption by 8,5% can be expected installing this new type of burner in the preheating zone of an existing furnace instead of conventional burners,
- the design of a new furnace only fitted with this kind of burner could increase the productivity by 17% and decrease the fuel consumption by 14%.

3.2 Simulation of the burner and simplified representation

The CFD approach has been chosen. The model obtained represents the physical phenomena (flows, thermal transfer, combustion, etc.) in a detailed manner. The methodology employed is firstly to pre-select the sub-models used to represent the industrial burners, and then to validate them from the detailed measurements in the flame. Figure 10 (a) represents the geometry of the NFK burner.

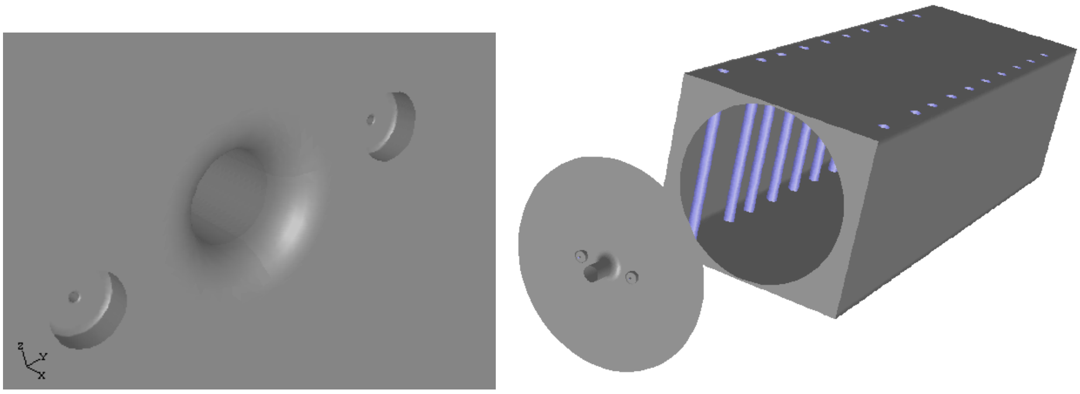


Figure 10 : (a) Injectors of the NFK HRS-DL Burner – (b) Combustion Cell

Figure 10 (b) shows the configuration of the test cell. The flame develops in a first cylindrical section, with a diameter of 900 mm. The second section is of parallelepiped form, and is penetrated by tubes which are water cooled, allowing to simulate the thermal load. The total length of the cell is 4.64 m. By considering the different symmetries, ¼ of the test cell has been represented.

The numerical simulation and experimental validation work has shown that it is possible to simulate a flameless oxidation burner with a CFD application, and standard turbulence, radiation and combustion models. Prediction of the aerodynamics and thermal fields is consistent with the experimental data.

A detailed model of this type is excellent in terms of accuracy, but cannot be implemented at scale of an industrial furnace at an acceptable cost. A simplification methodology has therefore been developed. This approach remains based on a CFD tool. The flow has been simplified, and the number of equations to be solved has been reduced. This is used to considerably reduce the size of the mesh, and to reduce the calculation time of several hours to a few minutes, while also maintaining a comparable degree of accuracy. This study has enabled to maximise the accuracy/calculation-time compromise, in relation to the detailed model. The strategy retained consists of simplifying the CFD model in two stages:

- representation of the jets of fuel and oxidiser by a single equivalent jet whose composition is that of the combustion products,
- representation of the combustion zone by a volume source term.

The accuracy of this simplified CFD model in relation to the detailed model has been assessed, and the minimum size of the mesh used to maintain an acceptable degree of accuracy has been determined. These conclusions have been implemented for simulation of the installation at semi-industrial scale in dynamic regime.

3.3 Study at semi-industrial scale and validation of the tools

Before using the tools at industrial scale, and simulating the installation in a complete manner, a preliminary task for validation of the tools has been conducted at semi-industrial scale. For this task, a test furnace has been specially designed and manufactured by Stein-Heurtey company. The pair of NFK regenerative burners tested previously has been tested in operating conditions close to a steel-maker's heating furnace. The objectives of the test programme were as follows:

- firstly to make up an experimental database in order to validate the modelling tools developed in parallel,
- to assess the performance of the flameless-oxidation burners in conditions close to those of an industrial furnace. It was particularly looked at the efficiency and the quality of heating (the NO_x emissions and the intrinsic performance of the equipment had already been analysed during the characterisation test),
- and finally to acquire a technical expertise enabling to scale up this technology at industrial application level.

3.3.1 Description of the test furnace.

The furnace, at semi-industrial scale, has the following characteristics:

- it is equipped with a pair of NFK HRS-DL 200kW regenerative flameless oxidation burners, positioned face to face, 3 metres apart and in an upper zone of the furnace,
- it is also equipped with a furnace loading/unloading system, used to introduce a slab of steel measuring 1m x 1m x 0.22m. For information, such a slab inserted at ambient temperature into a furnace at 1300°C reaches a temperature of 1200°C after more than 2 hrs 30 mins.

Figure 11 : (a) General view of the test furnace, (b) Internal view of the furnace

For this test at semi-industrial scale, a slab of conventional carbon steel, appropriate for the dimensions of the furnace, was supplied by Arcelor. A manual furnace loader, equipped with a hydraulic jack, was also specially designed in order to handle this slab, which was instrumented for temperature meausurement by means of thermocouples (see figure 12).

Figure 12 : Instrumented slab on its furnace loader

3.3.2 Main results.

The procedure was as follows:

- the furnace was brought up to stationary operation at its setpoint temperature. The heat demand was regulated in pulse mode,
- the slab was introduced into the furnace (see figure 13 (a)). The temperature of the furnace droped by several hundred degrees before progressively rising again (see figure 13 (b)),
- when the slab reaches the wanted temperature, it is then unloaded from the furnace (see figure 13 (c)).

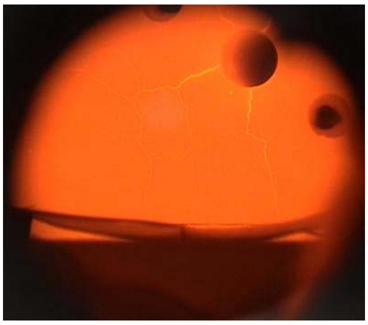


Figure 13 : (a) Loading of the slab, (b) Heating of the slab by the burners, (c) Unloading of the slab

The test programme was then executed during the month of June 2002, and in accordance with the set schedule. In general, operation of the burners raised no problem. Pulsed regulation of the furnace temperature was achieved properly.

For instance, figure 14 shows the graphs of temperature measured at the wall of the furnace and in the slab during the long-duration test. In this example, the furnace was stabilised to 1200°C. Just after loading, the cold slab causes the temperature fall of the furnace by almost 300°C (opening the door has negligible effect), before it begins to rise again progressively, to reach the setpoint temperature. The heat demand is 100% up to the moment when the setpoint is reached. At nominal thermal input (200kW), the heating time of the slab to attain 1100°C is about 140 minutes.

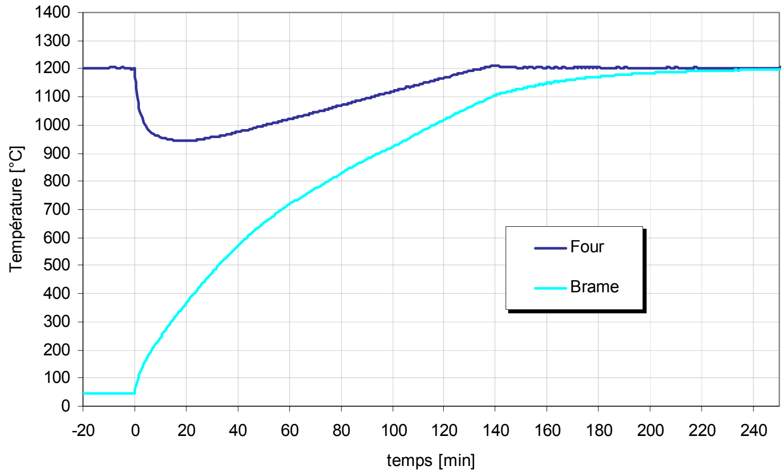


Figure 14 : Temperature curves obtained during the long-duration test

3.3.3 Conclusions of the semi-industrial test

The NFK HRS-DL regenerative flameless oxidation burners have been implemented in semi-industrial conditions. The measurements collected have enabled to validate the numerical tools developed in parallel within this project. In addition to the generation of an experimental database, this test programme has enabled to assess the general behaviour of the burners, i.e.:

- the levels of NOx emissions are very low and in agreement with the characterisation study conducted at Gaz de France,
- the combustion efficiency is over 85% in the reference operating conditions, and the combustion products leave the regenerative heat capacity at a temperature of less than 100°C, whatever the temperature level of the slab in the furnace,
- the pulsed regulation mode has turned out to be very satisfactory for the control of the burners, and offers advantages in terms of heating quality and control of the NOx emissions,
- the burners enable to achieve a very good thermal homogeneity in the length of the furnace,
- when the heat demand is low, the efficiency of the regenerative heat capacity falls down.

These tests, carried out with the loading of an instrumented slab (at different temperatures and for different operating conditions of the installation) result in a very valuable database for understanding, validation and specification of the tool use limits at the semi-industrial scale.

3.4 Simulation of the semi-industrial scale furnace in non stationary state

Two types of numerical simulation have been carried out in the framework of this study:

- a “conventional” CFD approach which makes use of the representation, in stationary conditions, of all of the physical phenomena taking place in the enclosure of the furnace,

- an overall approach, focused on a study of the non stationary thermal transfers. This approach has been used to obtain a numerical representation of the rise in temperature of a load in a “batch” type furnace.
  These results are compared with experimental data (figure 15).

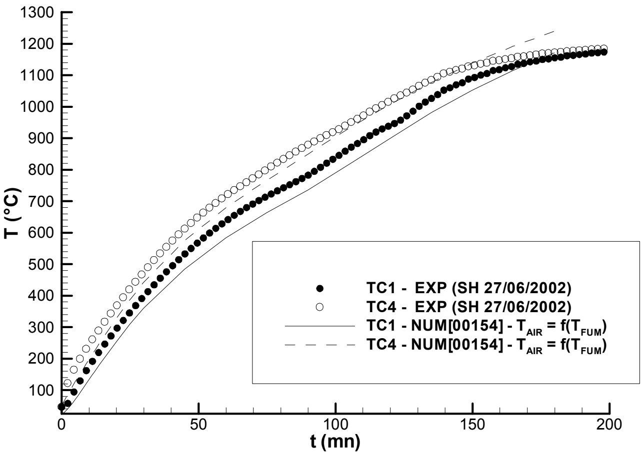


Figure 15 : Experimental and numerical temperature in the slab during the time in the semi-industrial test cell

The numerical tool, validated at semi-industrial scale, can be used to achieve the pre-dimensioning of an industrial installation.

4. VALIDATION AND DEMONSTRATION AT INDUSTRIAL SCALE

An industrial demonstration project is under preparation. For this industrial application, the installation of these new burners for the "boosting" of a heating furnace with a view to increase its capacity is planned.

This is an existing slab reheating furnace (see figure 16), whom production the steel maker wants to increase, while improving efficiency (in terms of consumption per ton of steel) and reducing NO_x emissions.

Figure 16 : Slab reheating furnace

The thermal input repartition inside the furnace in order not to have overheated point on the refractory lining and the prediction of the impact of these burners on the combustion products circulation inside the furnace was studied with the simplified representation described earlier.

Several burners configurations were tested, and CFD assessments showed that the installation of two pairs of 3MW burners upstream the heating zone gives the most interesting results.

5. CONCLUSIONS

Regenerative burners used in the flameless combustion mode are high-performance systems allowing by a pre-design optimization to significantly increase the productivity as well as reduce the CO_2 emissions.

Several manufacturers are now offering this type of burner, and industrial applications have been validated mainly in Asia (slab furnaces, billet furnaces, thermal treatments, etc.).

Measurements have also shown that low NO_x emissions can be achieved with this new generation of burners. The tests performed tend to demonstrate that the emissions remain below 300 mg/m3(n) at 3% of O_2, whatever the operating conditions (in particular with greatly pre-heated air or high furnace temperatures), and without altering the combustion yields.

Industrial demonstrations in Europe, in the various sectors including metallurgy, should appear in the coming months.

The design tools developed in the framework of this project , but also a better understanding of the combustion phenomena enable guarantees to be given regarding the performances and heating quality of the products.

Even though, the first industrial applications now mainly concern the metallurgy area, it is very likely that this new combustion mode will also be used, in the short or medium term, in other industrial sectors such as ceramics, glass-making, petrochemicals, gas turbines or industrial boilers.

It will be a concern less for the BAT determination process, as it will no more be necessary to make a trade-off between energy efficiency, productivity and NOx emission reduction...

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Franck Delacroix
BAT co-ordinator
EGTEI (Expert Group on Techno Economical Issues) agency leader
SOx, NOx and N_2O emissions of industrial processes

Plenary session

Producing more with less: Efficiency in Power Generation

ENERGY EFFICIENCY IN POWER PLANTS

Frans van Aart, Wim Kok, Pierre Ploumen

KEMA Power Generation & Sustainables

ENERGY EFFICIENCY IN POWER PLANTS

Frans van Aart, Wim Kok, Pierre Ploumen; *KEMA Power Generation & Sustainables*

1 INTRODUCTION

The purpose of the IPPC directive is to achieve integrated prevention and control of pollution, leading to a high level of protection of the environment. Information exchange between Member States and industries is used as a tool to issue reference documents on best available techniques (BREF) for all kind of activities. These BREFs provide reference information about applied processes and technologies for the permitting authorities to take into account when determining permit conditions. Energy efficiency is one of the topics to consider. Therefore a horizontal BREF about energy efficiency in IPPC installations will be prepared.

Large Combustion Plants for electricity supply are important installations covered by IPPC. It is to be expected that the BREF LCP will be issued by the end of 2004. Furthermore it is to be expected that based on the Emission Trading Directive the European Union Greenhouse Gas Emission Trading Scheme will commence operation in January 2005.

In this paper the trends on energy efficiency in power plants and the consequences of other relevant directives and guidelines on the permitting process for Large Combustion Plants (> 50 MW_{th}) will be presented.

Energy efficiency belongs to the core business of electricity companies. The industry therefore supports a policy to optimise energy efficiency. High energy efficiencies contribute to cost efficient operation, to conservation of fuels and to minimizing both all kinds of emissions and dependence of fuel import from outside Europe.

Definitions of energy or electric efficiency should be used very carefully. The differences between numbers for annual averages, standardised conditions, peak or average load et cetera are tremendous! Furthermore efficiency figures depend not only on the type of power plant but also on local circumstances which cannot be changed, such as temperature of cooling water and ambient air. These aspects should be taken into account when comparing energy efficiency figures with each other.

2 DEMAND SIDE MANAGEMENT

From an overall point of view it is desirable to reduce the energy demand as much as possible **before** planning the generation of electricity and heat. However, the responsibility for this phase lies with spatial planners, architects, industrial designers and so forth. It is the task of the electricity companies to supply the demand in the most efficient way after the demand itself has been reduced as much as possible by others. The scope of the IPPC-directive is limited to (large scale) installations. Rules on demand side management should according to (Eurelectric, 2004) create "framework conditions and not an over-detailed set of rules that could interfere with the development of the electricity market".

3 ENERGY EFFICIENCY OF POWER GENERATION

3.1 General

As figure 3.1 demonstrates, the efficiency is strongly depending on the type of generation and the fuel.

However, not all the types like hydro, nuclear and solar plants are IPPC installations. For this reason the following paragraphs only deal with thermal (non nuclear) power plants above 50 MW_{th}.

3.2 Factors determining the Electric Efficiency of Thermal Power Plants

As generally known the electric efficiency of power plants is improving all the time. Figure 3.2 illustrates this for all thermal plants within the countries of the original European Union (EU-15).

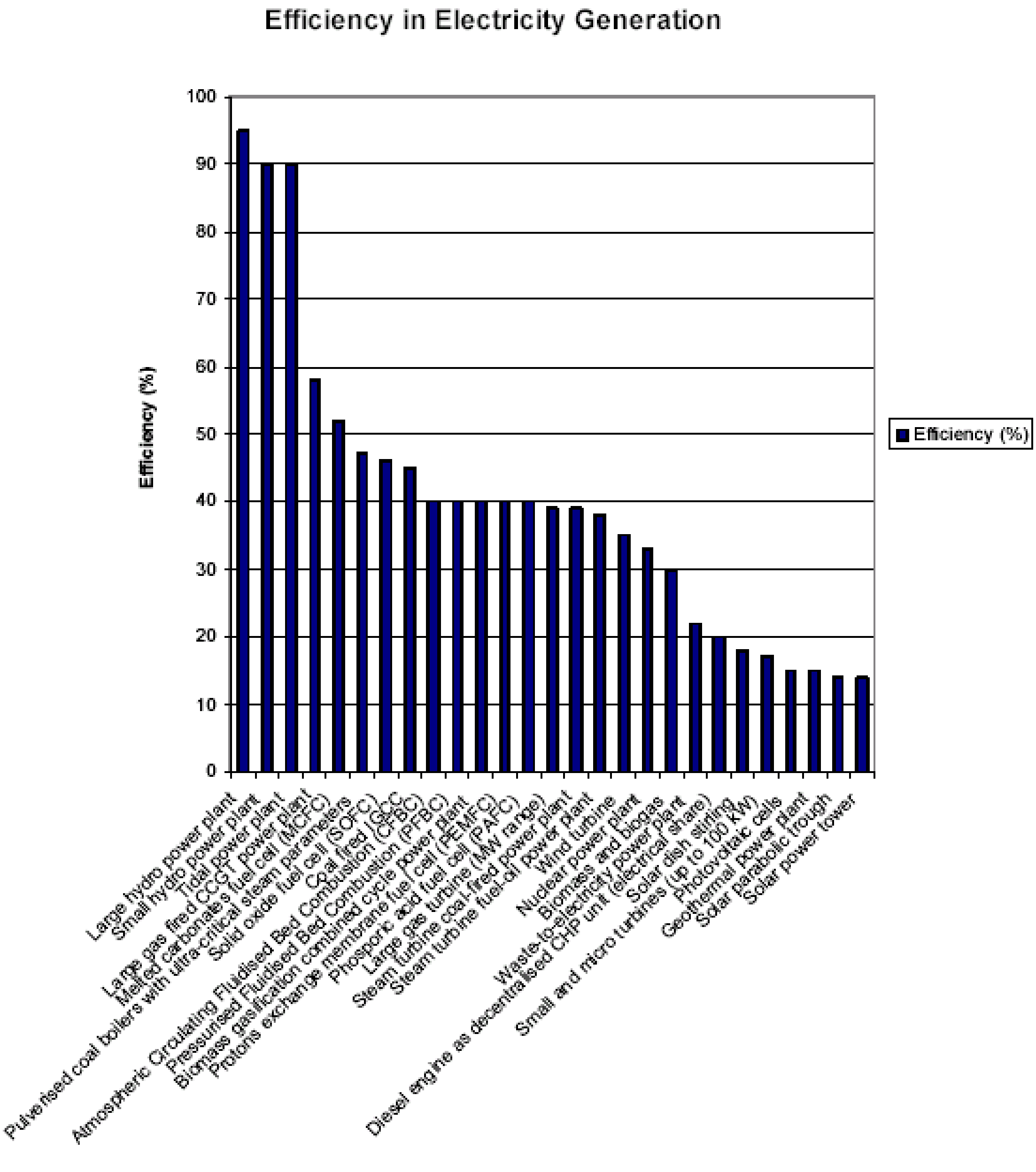

Figure 3.1 Typical energy efficiencies of new generation installations (Eurelectric, 2003)

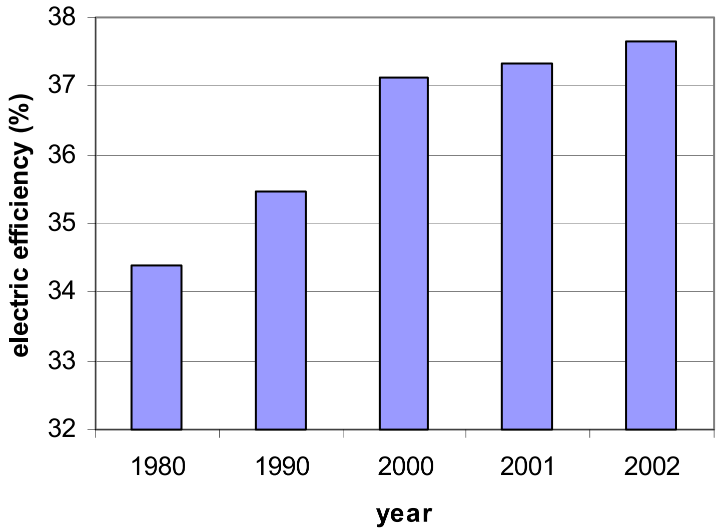

Figure 3.2 Average net electric efficiency of all conventional thermal power plants in EU-15 as a function of time (EURPROG, 2004)

The electric efficiency in general is not a fixed parameter for a certain installation. Main parameters which determine the average electric efficiency are:

a type of installation (e.g. combined cycles or steam boilers)
b age of the installation
c quality of combustion
d operating load and number of start-stops
e maintenance condition
f type of cooling (water or air, once through cooling or cooling tower, type of cooling tower)
g temperature of cooling water or air
h temperature and humidity of combustion air
i type of fuel and fuel quality.

Since some of these parameters can not be influenced by man at all, they are also impossible to regulate.

Figure 3.3 illustrates as an example for once through cooling that the electric efficiency depends strongly on local conditions as the temperature of cooling water.

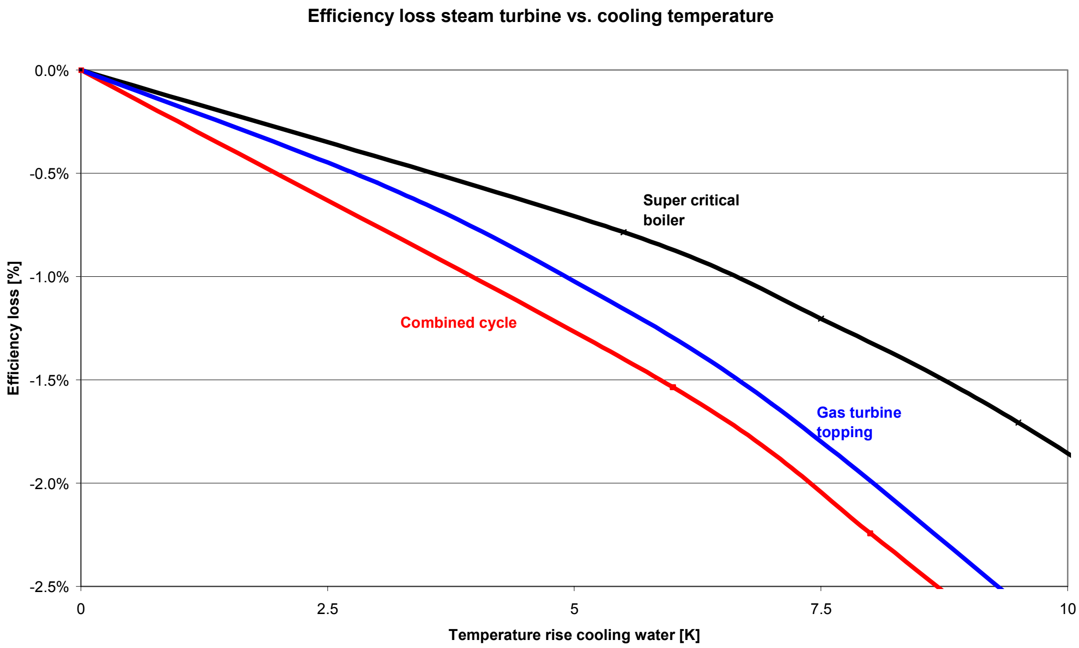

Figure 3.3 Efficiency loss due to higher (once through) cooling water temperatures (KEMA, 2004)

Other factors, like maintenance, can be influenced but are also limited by economic and operational considerations, like availability and reliability. In general regulators should not take over the driver seat of the electricity industry in balancing all economic and operational factors.

Together with the manufacturing industry the European electricity companies are researching and developing plants with higher efficiencies, as plants of these types provide to both a competitive advantage. General developments are higher temperatures in gas turbines and steam boilers in order to improve the so-called Carnot efficiency.

The following paragraphs provide the trends for gas turbine based and steam boiler based power plants, which are the two main types of Large Combustion Plants.

3.3 Trends in gas turbine based LCP

Table 3.1 provides typical efficiency numbers for new plants over the years. Further improvements are foreseen in the near and later future. The improvements are primarily connected to better materials allowing higher firing temperatures in gas turbines and higher (super critical) steam conditions in the heat recovery steam generators.

Table 3.1 Typical average values of electric efficiencies of combined cycles (VGB, 2001)

	1985	**2000**	**2010 (estimation)**
Combined Cycle	48	58	60

Gas turbines are proven technology for gas (and some types of oil) fired power plants and are preferred above steam boiler based LCP. Integrated Coal gasification combined cycle merges gasification, gas cleaning and gas turbine technologies to produce electricity with high efficiency and low emissions. Up till now only a few coal gasification plants are in operation. Coal gasification is considered as an interesting but still emerging technology.

3.4 Trends in steam boiler based LCP

The efficiency of new coal plants has also been raised by application of higher pressure and steam (up to ultra super critical) conditions made possible by better boiler materials. This is illustrated in figure 3.4.

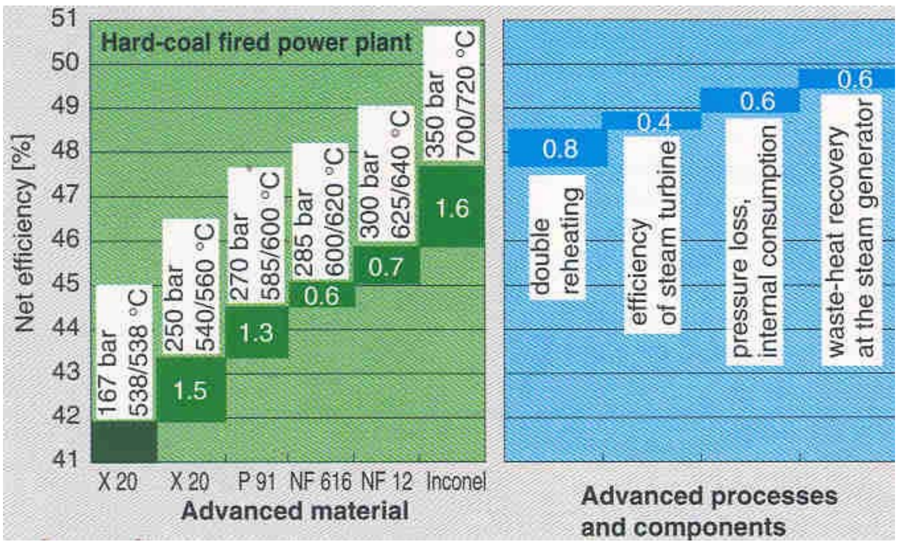

Figure 3.4 Advanced materials, processes and components for improved coal technologies (VGB, 2001)

The possible pressure has roughly doubled and the steam temperature raised with about 30%. Other important improvements are:

- double reheating
- improvement steam turbine efficiency
- reduction of internal energy consumption (house load).

Table 3.2 presents the development of efficiencies in new coal fired plants.

Table 3.2 Typical average values of electric efficiencies of new coal plants (> 400 MWe)

	1985	**2000**	**2010 (estimation)**
Steam boiler based LCP	38	47	50

Retrofitting existing plants may provide also interesting efficiency improvements; typical values of 30-40% are attainable. In case of extension of the power capacity of a site, integration of a gas turbine into the steam boiler (e.g. gas turbine topping) may provide excellent opportunities to raise both efficiency and power output.

3.5 Other techniques and fuels

Renewable energy sources will develop further in the coming decades. Plants firing biomass will contribute more to the electricity production than nowadays. Steam conditions of stand alone biomass fired power plants are moderate, resulting in relative lower efficiencies compared to fossil fuel fired power plants. It is to be expected that improvement of design and materials will increase the efficiency of stand alone biomass fired power plant in the future.

Co-combustion of biomass in large coal fired plants offers much higher efficiencies. Co-combustion rates of up to about 10% w/w can be reached nowadays. It is to be expected that in the future higher rates are feasible.

3.6 Co-generation

The combined supply of heat and power, co-generation or CHP, is a powerful instrument for improving the “efficiency” of a power plant. The term “efficiency” is put between quotation marks since this term is used as the ratio between the delivered energy (both electricity and heat) and the fuel energy input. The delivered electricity and heat represent different types of energy (with a different exergy level) that cannot be added together just like that. The ratio is a good measure of the amount of fuel that is utilised efficiently and therefore it is proposed to use in case of co-generation the term “fuel utilisation rate” instead of efficiency.

Co-generation can lead to fuel utilisation rates of up to 90%. These high rates can only be achieved when the heat demand is attuned to the electricity production and relatively constant over the year. The heat demand for district heating varies per day and over the year, and the demand of process heat depends strongly on the heat requiring industries.

Furthermore the heat demand shall be ensured for the complete life time of a power plant in order to make co-generation cost-effective and feasible. In this context reference is made Article 6 of the LCP Directive:

> *“Member States shall ensure that the technical and economic feasibility of providing for the combined generation of heat and power is examined. Where this feasibility is confirmed, bearing in mind the market and the distribution situation, installations shall be developed accordingly.”*

4 OTHER DIRECTIVES AND GUIDELINES

The Energy Efficiency BREF, is a so-called horizontal BREF, describing energy efficiency for many categories of industrial activities. For Large Combustion Plants also other directives and guidelines are relevant:
- Emission Trading of Greenhouse Gases
- Large Combustion Plants Directive
- Integrated Pollution Prevention and Control Directive and BREF LCP
- Renewable Energy Sources.

Article 26 of the Emission Trading Directive describes the following amendments of the IPPC directive:

> *“…the permit shall not include an emission limit value for direct emissions of that gas unless,...”*

and

> *“…Member States may choose not to impose requirements relating to energy efficiency in respect of combustion units or other units emitting carbon dioxide on the site.”*

We support this amendment. The market mechanisms of emission trading will result in an optimal efficiency of power plants. In our opinion fixed efficiency figures or BAT to be applied in Large Combustion Plants should not be prescribed by permitting authorities. Instead of this electricity companies can be requested to demonstrate that the energy efficiency is as high as economically feasible.

Several approaches can serve this goal. We will mention here two options:
a Benchmarking Energy Efficiency
b Energy Plans.

The first option is applied in the Netherlands and was proposed by industry itself to prevent specific efficiency rules. In a covenant with the national government the industry obliged itself to belong to the “world top” as to energy efficiency for installations with capacities above 20 MW_{th} by the year 2012.

The state Flanders of Belgium issued a regulation that obliged owners of installations consuming more than 0.5 PJ/year to draft an Energy Plan. This plan should contain all measures that can improve energy efficiency in an economic way. The criterion “economic” is specified as providing an internal rate of return of at least 15%.

5 CONCLUSIONS

A high energy efficiency of power plants has always been a primary goal of the electricity industry over time again and again. During the last decades the efficiency of power plants is increased considerably. Also in the short and long term future extra improvements are expected in both gas turbine based as steam boiler based Large Combustion Plants, as the economy in a free market also requires optimum (energy) efficiency.

The CO_2-emission trading to be introduced in 2005 within the EU will effectively mean higher fuel costs and so provide an extra incentive to improve energy efficiency. Under these market conditions energy efficiency is also a key factor for competition with other companies.

In line with Article 28 of the Emission Trading Directive we propose not to describe BAT or BAT levels concerning energy efficiency of Large Combustion Plants in the BREF on Energy Efficiency.

Rules to demonstrate the use of optimal energy efficiency measures at a certain plant could be considered. Drafting energy plans (perhaps in combination with Benchmarking) could serve this goal.

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Parallel session
Innovative energy efficiency examples of different industrial sectors –
Energy efficiency in pulp & paper and sugar industry

OPTIMISATION OF STEAM AND CONDENSATE SYSTEMS OF PAPER MACHINES

Gerald Bachmann
Allplan GmbH
Schwindgasse 10, 1040 Vienna, Austria
E-mail: gerald.bachmann@allplan.at

OPTIMISATION OF STEAM AND CONDENSATE SYSTEMS OF PAPER MACHINES

Gerald Bachmann, *Allplan GmbH*

1. Introduction

In paper mills steam is used for drying wet paper. Therefore extremely complex steam and condensate systems are utilized.

These systems consist of the following main parts with the following functions:

1. Different heating groups with heating cylinders for heating and drying the paper.
2. Separators at the end of every heating group are installed for the separation of vapour and condensate of each heating group.
3. Vapour heat exchanger in the hood air heating system are installed for the condensation of the vapour with the lowest pressure at the last separator.
4. Auxiliary condensers for total condensation of none condensated vapour.

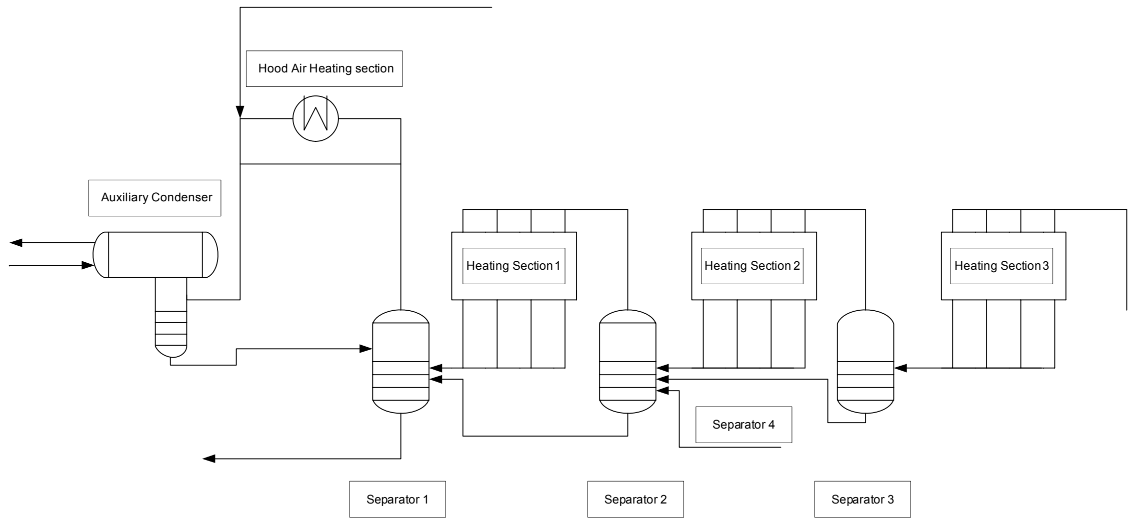


Figure 1: Steam and condensate system of a paper mill

Each different heating group requires a different necessary pressure for optimal drying of the paper. Due to the fact that it is always tried to increase the velocity of the paper machine there are always changes necessary in the steam and condensate system (putting an heating cylinder from one heating group to an other, increase or decrease the pressure in different heating groups,…). Due to these changes it is difficult to find the optimum mode of operation.

There are two main possibilities to identify better operating conditions for the steam and condensate system of paper machines. These two possibilities are:

1. Simulation
2. Experiments without influences on the production

With a simulation model the paper machine could be analysed and optimized. The result meets the reality quite closely. With special experiments during normal production an optimization potential can be given.

2. Simulation

Creating good quality simulation models is quite difficult because of the complexity of the steam and condensate systems. The first step is creating the model and the second to feed the model with data (first existing parameters and then choosing the last unknown parameters).

2.1 Creating the Simulation Model

There are different programs like Aspen or Ipse which could be used to create the model. In the model creating process all relevant equipment and processes have to be built up in the model. The following picture gives the main part of a certain simulation model of an existing paper mill, which was optimized using the simulation.

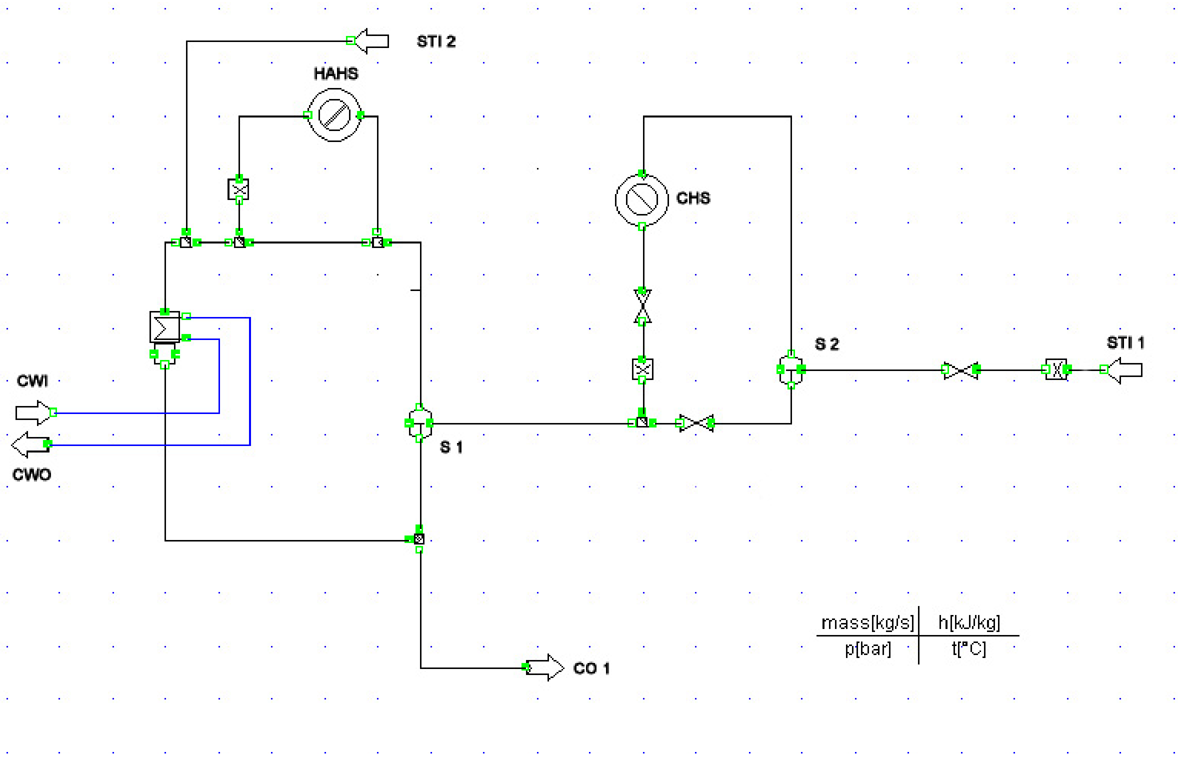


Figure 2: Main part of the steam and condensate system model of a paper mill in Austria

The model in the figure above consists of steam input (STI 1), separator 2 (S 2), cylinder heating section 1 (CHS), separator 1 (S 1), condensate output 1 (CO 1), hood air heating section (HAHS), steam input 2 (STI 2), condenser (C), cooling water input (CWI) and cooling water output (CWO).

2.2 Feeding the Model with Data

After creating the simulation model the data must be entered. Therefore the values

- mass flow in kg/s
- pressure in bar and
- temperature in °C

have to be entered. The last value

- enthalpie in kJ/kg

could be calculated by the simulation model program.

Some data is easy to fill in because these parameters are well known. In this certain simulation model this is all data of the cooling water input and output, the condensate output 2 and the hood air heating section.

The unknown data has to be assumed. After assuming the unknown data the model has to be checked by experiments. With these experiments different production situation could be simulated and the results of the simulations could be compared to the reality. In the following two figures parameters of different production situation are given.

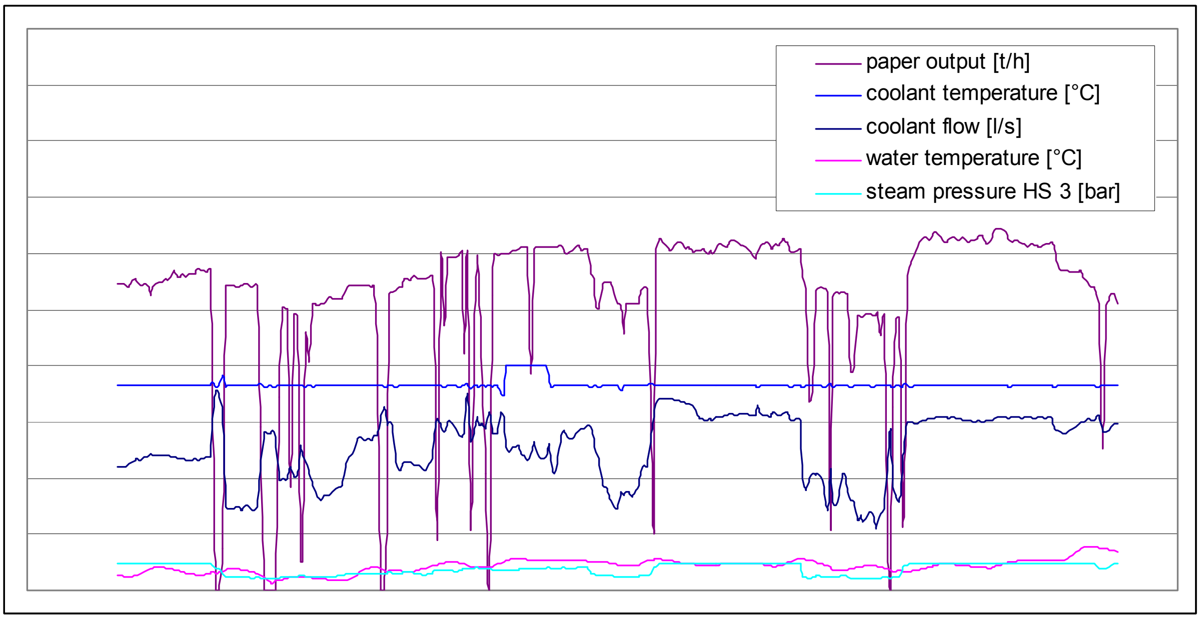


Figure 3: Parameter 1

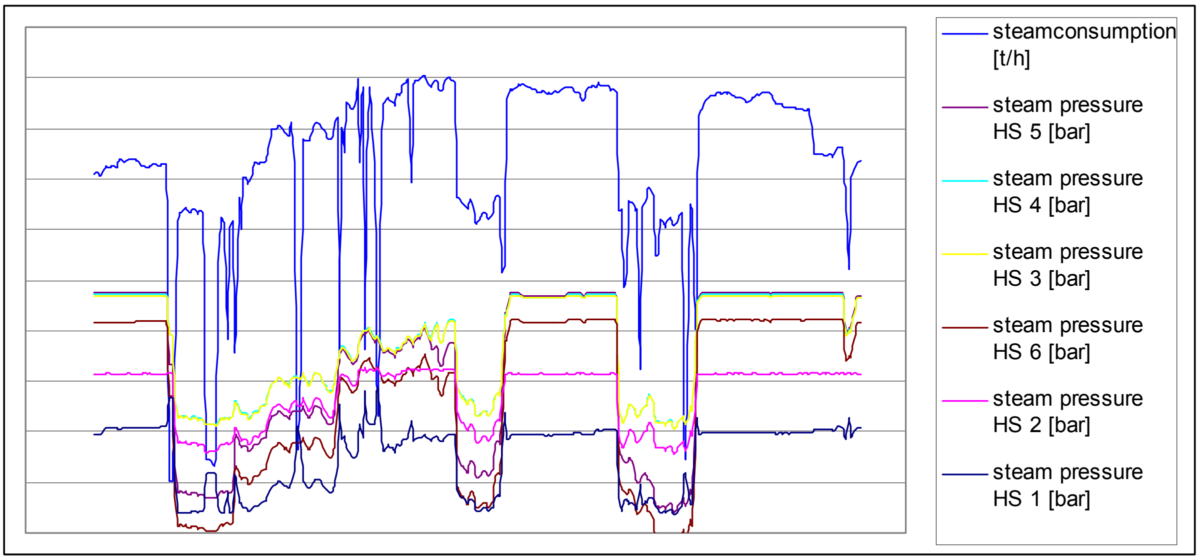


Figure 4: Parameter 2

After entering in these parameters into the simulation model, a technical conflict should not occur. If there is a conflict, the model has to be corrected. The following figure shows the correct simulation model.

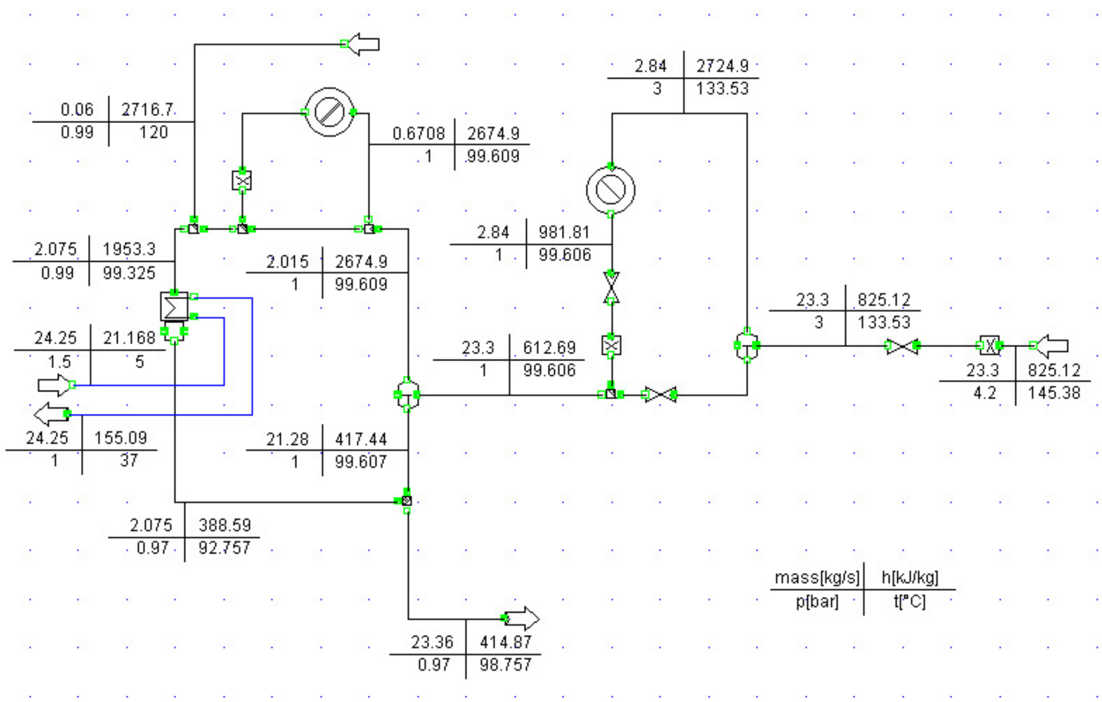


Figure 5: Correct simulation model

2.3 Simulation Calculation

After crating a correct simulation model, different scenarios could be calculated. For example the partly separating of condensate after separator 2 which results in a dramatic reduction of flow of cooling water. The following figure shows, that partly separating 20.45kg/s of condensate after separator 2 the cooling water flow will be reduced from 24.25 to 1.974 kg/s (marked red).

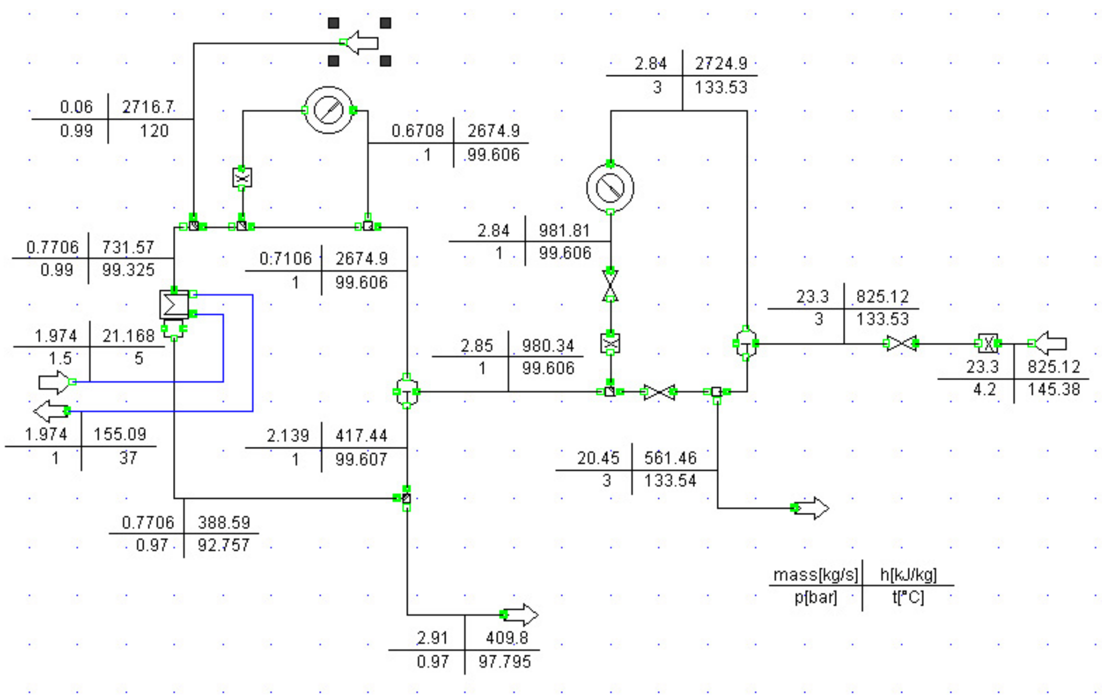


Figure 6: Simulation of taking off condensate

Due to the fact, that the energy is not heating the cooling water it is possible to use this energy at a level of 133°C. The energy saving is about 3MW and with 8000 operating hours per year the savings are 24GWh/year and more than 300.000€/year.

3. Experiments without influences on the production

Beside the simulation experiments without an influence on the production could be a possibility to reduce energy demand. Therefore with a high level of knowledge of steam and condensate systems different experiments could be selected and should be carried out very carefully.

The most important aspect in carrying out these experiments is that the production is operating during the experiment and the quality of the product and the capacity of the process are not decreasing.

While carrying out these experiments it is very useful, if a process control system is installed where all relevant parameters are shown. These relevant parameters have to be observed during the entire experiments.

Changing defined values such as the position of a valve results in changing the conditions and could lead to energy savings. For example the simulation case above that could mean the following:

- without any simulation it is assumed, that the energy of the condensate from separator 2 is not necessary for the vapour production in separator 1
- therefore an outlet valve at the bottom of separator 2 is slowly opened and a valve at the connecting tube between separator 2 and 1 is slowly closed

The result of this experiment is the same as in the simulation, the cooling water flow decreases.

4. Summary

There are two main possibilities to identify better operating conditions for the steam and condensate system of paper machines. These two possibilities are

- Simulation
- Experiments without influences on the production

An example is given for these two possibilities. The optimization of the steam and condensate system in this case leads to 3MW savings which means 24GWh/year respectively more than 350.000 Euros per year.

Allplan carried out such energy optimization several times in Austria as well as in other countries like Switzerland, Germany, Netherlands or Slovenia and found savings each time from several 100kW up to several MW.

Parallel session
Innovative energy efficiency examples of different industrial sectors -
Energy efficiency in pulp & paper and sugar industry

Examples about two energy saving measures in the pulp and paper industry on the site of M-real Hallein AG

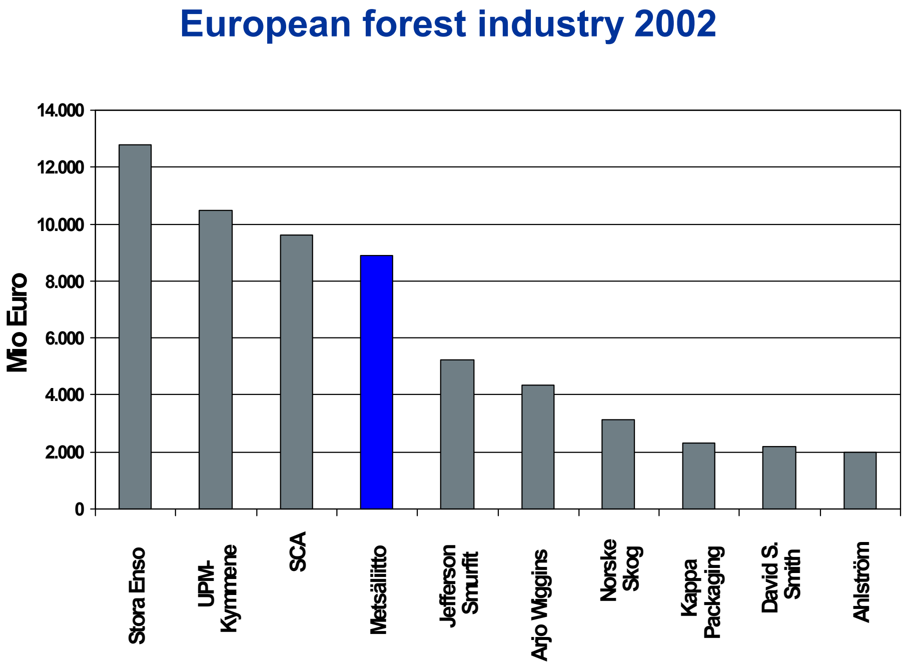
Erich Feldbaumer
M-real Hallein
E-mail: erich.feldbaumer@m-real.com

EXAMPLES ABOUT TWO ENERGY SAVING MEASURES IN THE PULP AND PAPER INDUSTRY ON THE SITE OF M-REAL HALLEIN AG

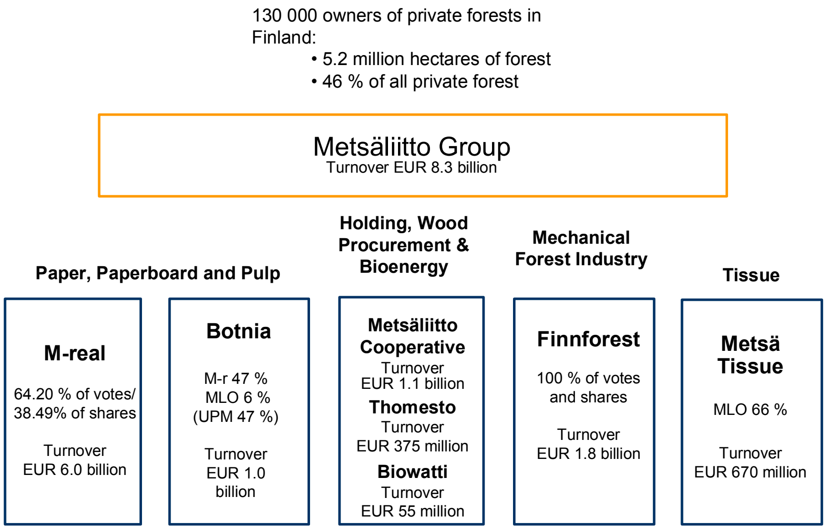
***Erich Feldbaumer**, M-real Hallein*

Introduction

M-real Hallein AG is a pulp and paper mill near the town of Salzburg and a subsidiary of the M-real group which on its part is a member of the Metsäliitto corporation, the 4 th biggest player in the European forest industry.



Metsäliitto Group 2003

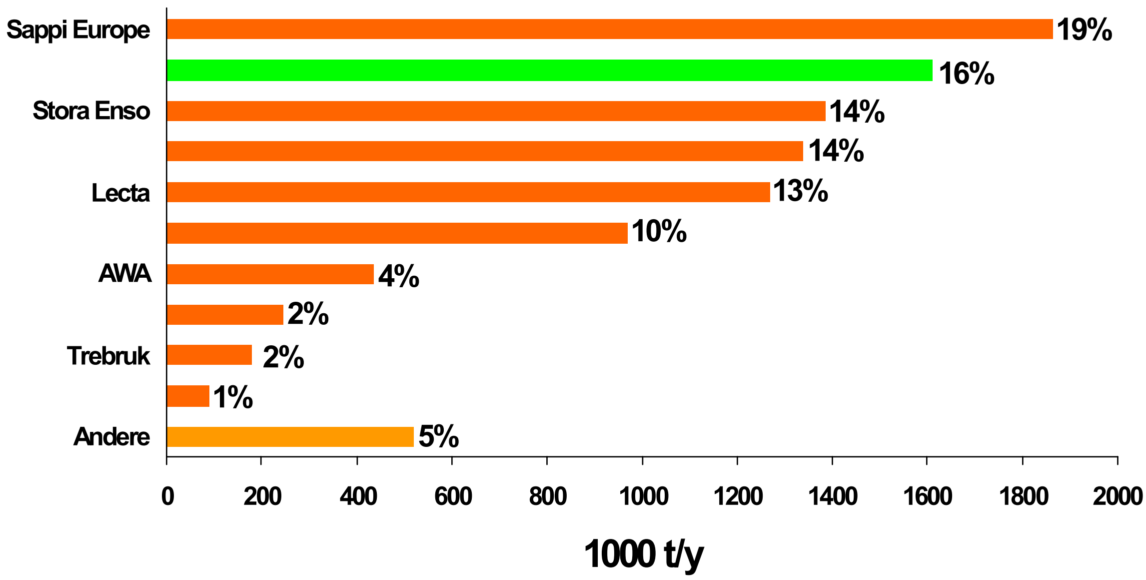


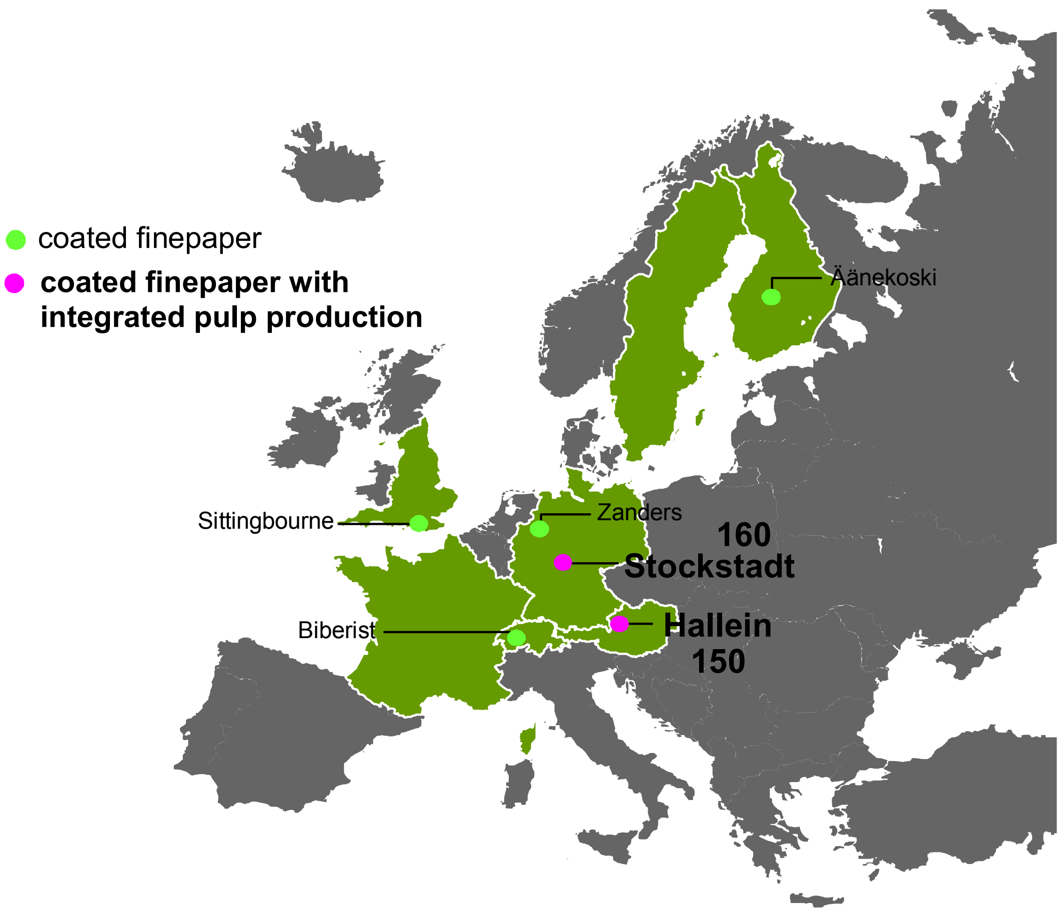
M-real is one of the leading paper and board producer in Europe with the head quarter in Helsinki. The group has production locations on 29 sites in Europe and produces with 19. 600 employees about 6 Mio t paper and paperboard. The products are delivered in more than 70 countries worldwide. In 2003 the turnover was 6 billion Euro.

Main area of operations

The main suppliers of fine paper beside M-real are:

Coated fine paper in Europe 2003





M-real produces its fine paper at following locations.

M-real Hallein AG:

In Hallein we employ 770 co-workers und 30 trainees.

Between 1983 and 2003 144 Million Euro had been invested in environmental improvements and we received the EMAS certificate 2003.

In 2003 the turnover was : 221,2 Million Euro, the export-rate was 95%.

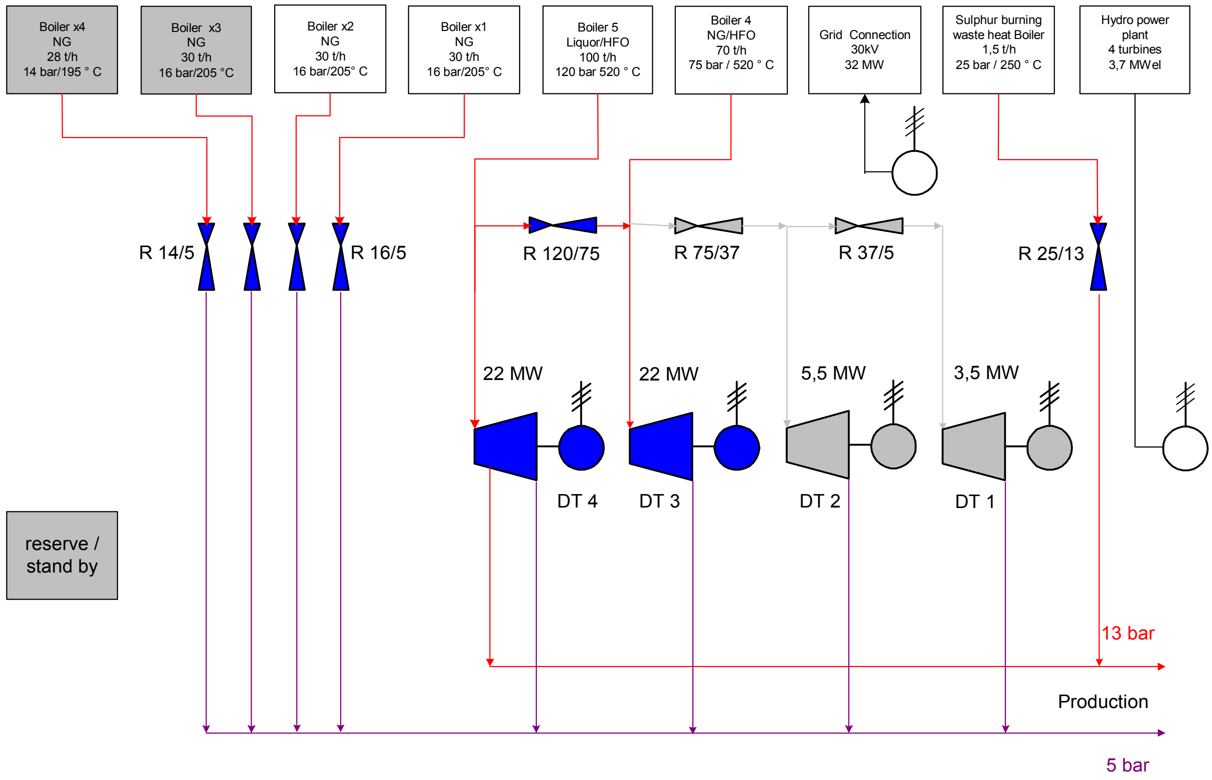
The production capacity is about 150.000 tons TCF- sulphite pulp and about

310.000 tons coated paper per year.

For this production there is a consumption of about 230 GWh electricity and about
1300 GWh heat per year.

This consumption is produced with several steam boilers and steam turbines which are operated with about 50 % fossil and 50 % biomass based fuels. Due to this big energy demand, it is a fundamental interest to have a strong energy management and to realize energy saving measures.

Energy flow diagram



Heat recovery from the exhaust gas of a sulphite liquor recovery boiler

General

Already 1997 in the framework of the SANS (Salzburger-Abwärme-Nutzungs-Studie), a lot of waste heat sources were detected in our mill. Beside much low temperature sources, a potential of approximately 3,85 MW recognized in the exhaust gas of the liquor combustion was recommended for an utilization as a matter of priority because of its high temperature level.

The realization failed for the moment because of the relatively high investment costs, round 2,8 million €, for the heat extraction and the at that time not economically re-presentable district heating network expansion (cost estimation 3,6 million €). The main problem with the network expansion was the selling of approximately 8500 hours available waste heat quantity per year could not be guaranteed.

In the year 2001, the project was taken up again from a newly founded district heat –Ltd. The heat extraction technology was completely revised and thereby investment costs strongly reduced. The Halleiner heat network was widened at the same time and the necessary heat sales were guaranteed with it. The realization of the project took place in conclusion with AESG (Alternative Energy Salzburg Ltd),in which the following companies are involved.

- Salzburg INC.
- Salzburger Erneuerbare energy - Ltd and
- Wärmebetriebe - Ltd

Through the use of improved technology and taut project organization, the total project (extraction part, transfer station, heat network connection and network expansion), had been able to be balanced with an entire expenditure of 3,5 million €.

The investment and the heat business are in the sole responsibility of and the risk of the AESG . M- real actually supports this non-polluting measure through free allocation of the heat during the pay-back-time, as well as through support with the operation management and maintenance. The investment costs were promoted by the Kommunalkredit Austria INC. with a subsidy level of 30 percent.

Technologic conditions and risk analysis

As a basic principle is the technology of heat shift in the exhaust gas of conventional fossil fired boiler plants state of the art. Especially in connection with wet waste gas desulphurization plants it is already used in the form of heat displacing systems to re- heat the cleaned flue gas.

The corrosive conditions with burning high sulphurous coals resulted already at conventional plants to the construction of Teflon heat exchangers. Those caused problems in connection with the remaining dust load contained in the flue gas, to perform the required surface cleaning.

This experience in connection with liquor combustion plants lead to qualified skepticism, considering, that the SO2 concentration after a liquor firing (approx. 30.000 mg/Nm3) is approximately 5 times higher than at a fossil firing (HFO 1400 mg/Nm3, coal up to 10.000 mg/Nm3). In the exhaust gas of the liquor firing there are also chloride components and considerably higher dust loads as permissible at conventional combustion plants.

As a first measure, the effects of the indirect heat exchange on the operation of the flue gas desulphurization plant had to be estimated and here in particular the saturation temperature in the raw acid generation stage (1st desulphurisation plant stage).

Under the prevailing plant circumstances the following parameters are influenced:

- The way of waste gas cooling (quenching or indirect heat exchange)

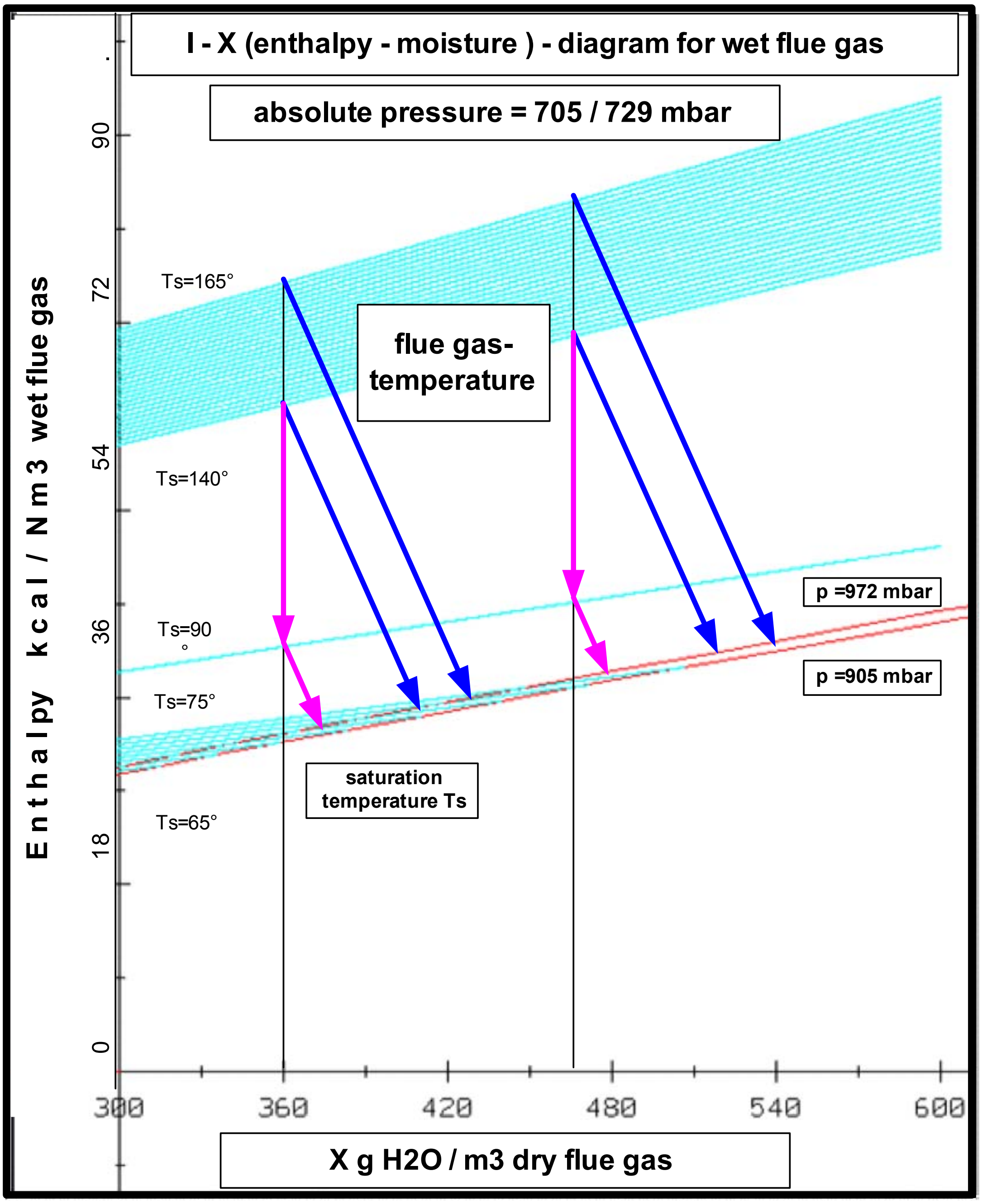
- absolute pressure in the flue gas scrubber (depends on boiler load and fouling in the scrubber stages)

- humidity content of the flue gas before the desulphurisation plant (this is influenced by the water content of liquor, the inserted atomiser steam quantity and the required soot blowing steam quantity)

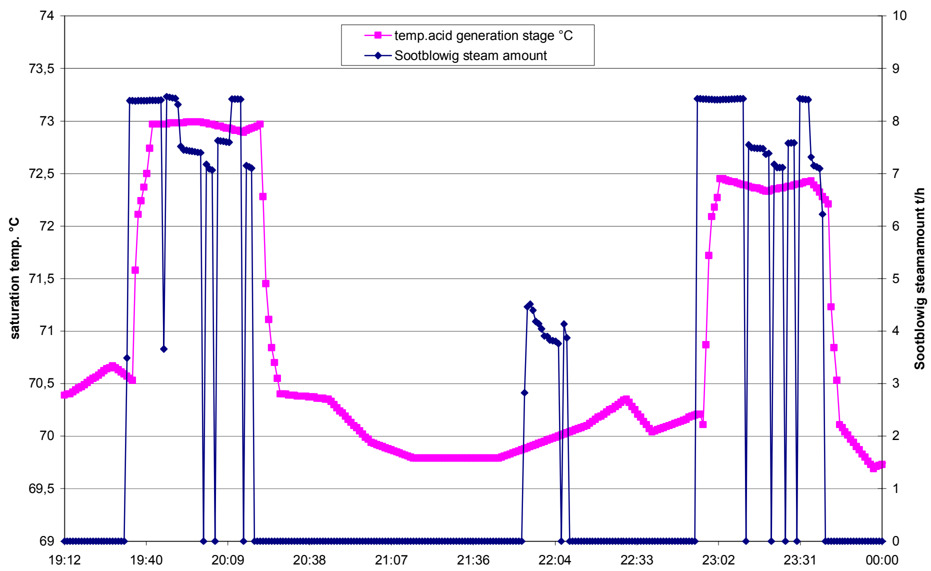
-temperature of the flue gas (it is dependent from fouling in the boiler heating surfaces and the boiler load)

parameter variation				
	dimension	***average***	***max.***	***min.***
content of solid matter in the liquor	**% DS**	***55,38***	***58,03***	***51,2***
atomizing steam amount	**kg/t liquor**	67	84,9	51,4
soot blowing steam amount	**t/h**	3,124	4,105	2,073
barometric pressure	**mbar**	965,0	986,0	954,1
variation of flue gas pressure	**mbaru**	33,1	14,4	49,5
absolute pressure in the acid generation stage	**mbar**	931,9	971,6	904,6
	mm_mercury	699,0	728,8	678,5
variation of flue gas temperature	***°C***	151,9	165	138,5
average burned liquor amount	**t/h**	35,66		
HFO amount	***kg/h***	633,2		
atomizing steam amount	**kg/h**	2389,2	3027,5	1832,9
soot blowing steam amount	**kg/h**	3124,0	4105,0	2073,0

To estimate which effects those indirect flue gas cooling through a heat exchanger before the existing quench cooler has on the raw acid generation stage, the extremes of the parameter variations occurring in normal operation were opposed the effect the indirect cooling.



As you can see from the represented data, the effects through the indirect heat extraction are in the same magnitude as they are caused through the changeable operating parameters in normal operation. As a positive effect the drop of the saturation temperature by approximately 2 ° C must be mentioned (this hypothetical value could also be verified during the test phase by measurement).



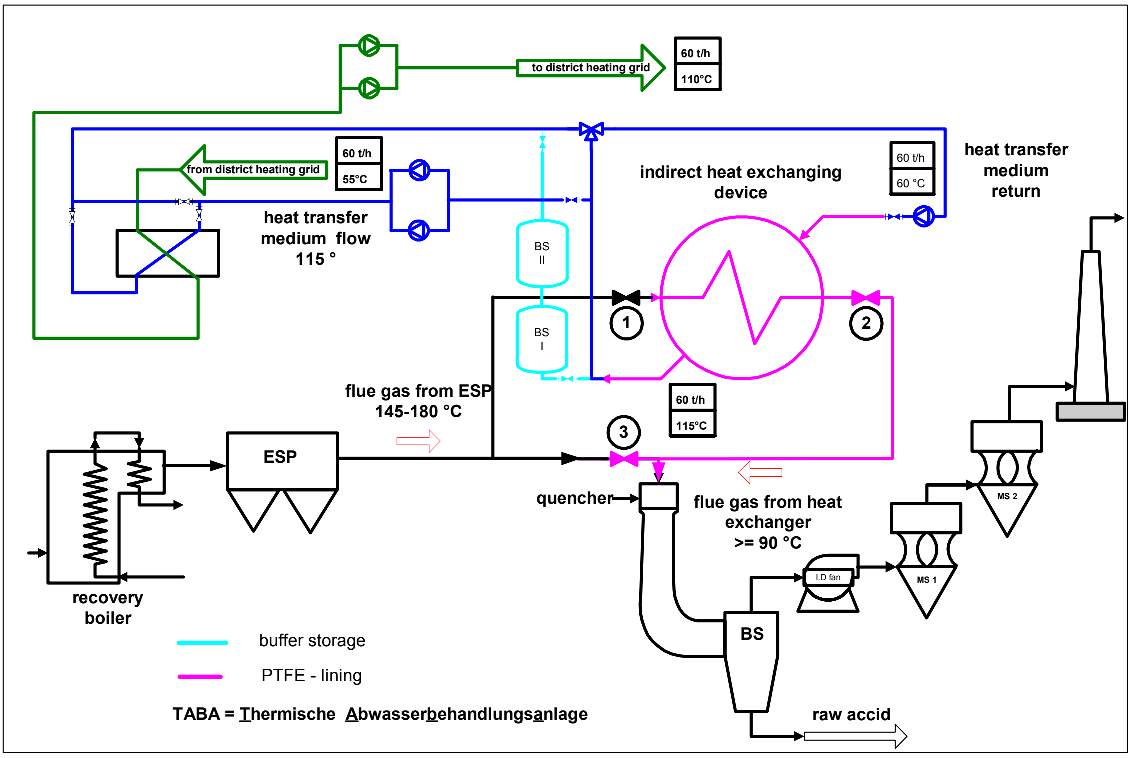
Fehler! Keine gültige Verknüpfung.

Effects of scaling on the heat exchanger surfaces.

The dust content after the ESP lies in the range of 50 mg/Nm3 in normal operation, it can increase to approximately 500 - 1000 mg/Nm3 in the case of failiers with one of the two filter fields. In order to be able to guarantee the function of the heat exchanger under these conditions it was divided into 3 sections. These sections can be washed separately to limit the temperature variation in the flue gas. In every section, a washing device is supplied by means of a rotatable spraying tube so all pipes of the exchanger can be overlapped with cleaning liquid.

Realization

Considering the assumptions described above, an complete solution in accordance with the next scheme.



The following criteria have to be addressed:

In order to guarantee a trouble-free operation of the liquor combustion and/or of the flue gas desulphurization plant the heat extraction was constructed in a bypass. It is through three special flaps at any time to separate from the flue gas flow. Flap 3 is carried out as a control devise, with that the thermal capacity to be extracted can be controlled.

The flaps were provided by the company Raumag-Janich-Systemtechnik Ltd..

The main demand to flap 1 and 2 was a highest possible tightness in order to guarantee admission to the heat exchanger in damage case under working conditions. Main attention at flap 3 was the full effectiveness over the entire running period since only via releasing the flue gas through this flap without essential pressure loss, the trouble-free operation of liquor combustion can be guaranteed.

To ensure the tightness of the flaps outwards and/or to prevent occurrence of corrosion by sucked, cold, moist ambient air, all passages through the flue gas duct walls are loaded with hot blocking air. That air is taken after the air heater of the liquor boiler at a temperature level of approximately 360 ° C.

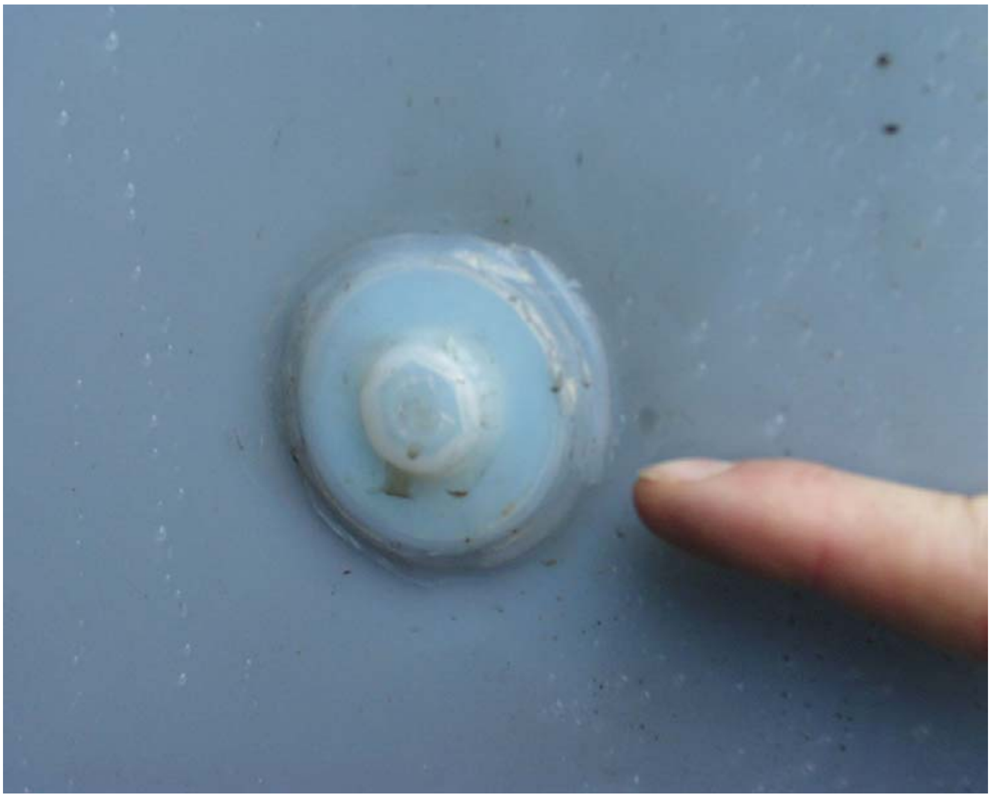
The core piece of the plant is the heat exchanger. In normal operation the flue gas ought be cooled down not further than to 90 ° C. However, trials are also planned up to the point of condensation. In this case, it comes to a continuous change between dry and wet conditions in the area of the heat exchanger. Due to continuous alternation between condensing and evaporating as a result, this zone is characterized, by an increasing concentration of corrosive gas components. That leads to extreme corrosion loads for the heat exchanger materials. To master that burden demanded the application of extreme expensive materials or how realized in our case to build up a combined protection mechanism.

We decided in favor of a tube bank heat exchanger of the company Flucorrex .

In this case, the required corrosion resistance is achieved by steel tubes enamelled in a two shift procedure with PTFE coating. This multi-layer construction takes especially well into account the different attack qualities of the involved corrosive gas and/or liquid components.

All parts behind the heater exchanger and/or the bypass flap up to the central tube of the existing flue gas quench cooler were provided with a PFA lining to prevent corrosion damages in case of falling below the local point of condensation

The PFA -lining is attached with a specific bolt- nut system, which is provided with welded PFA-caps on the gas loaded side.

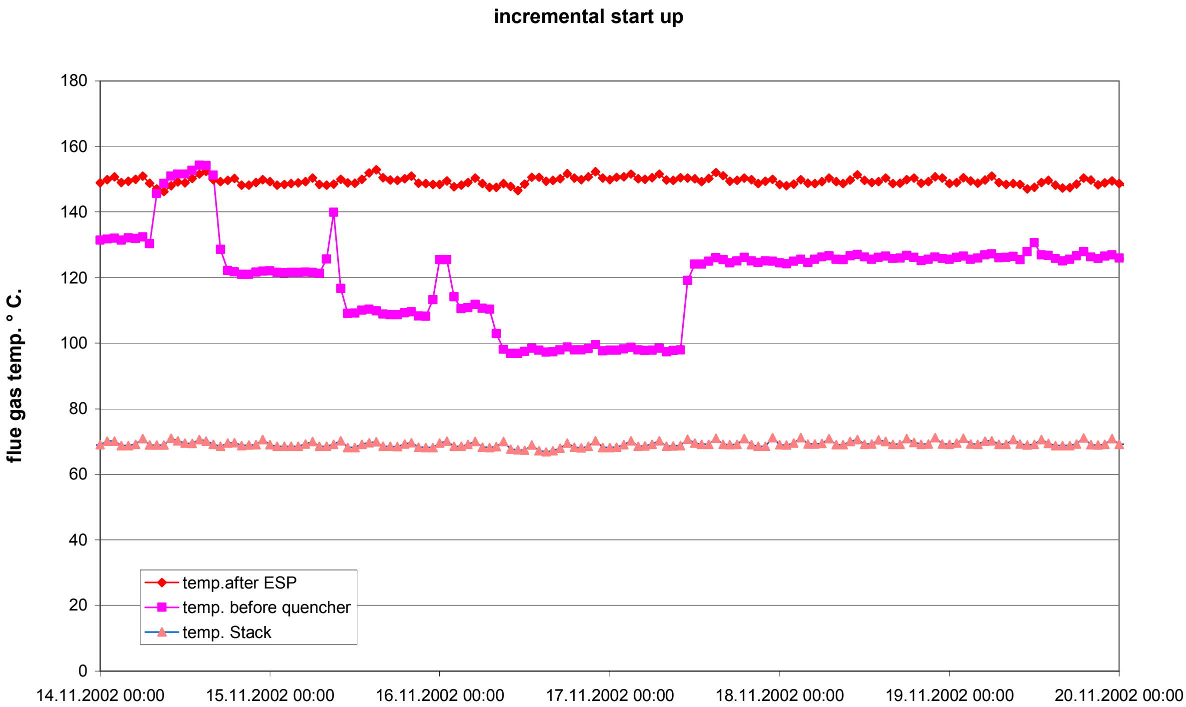


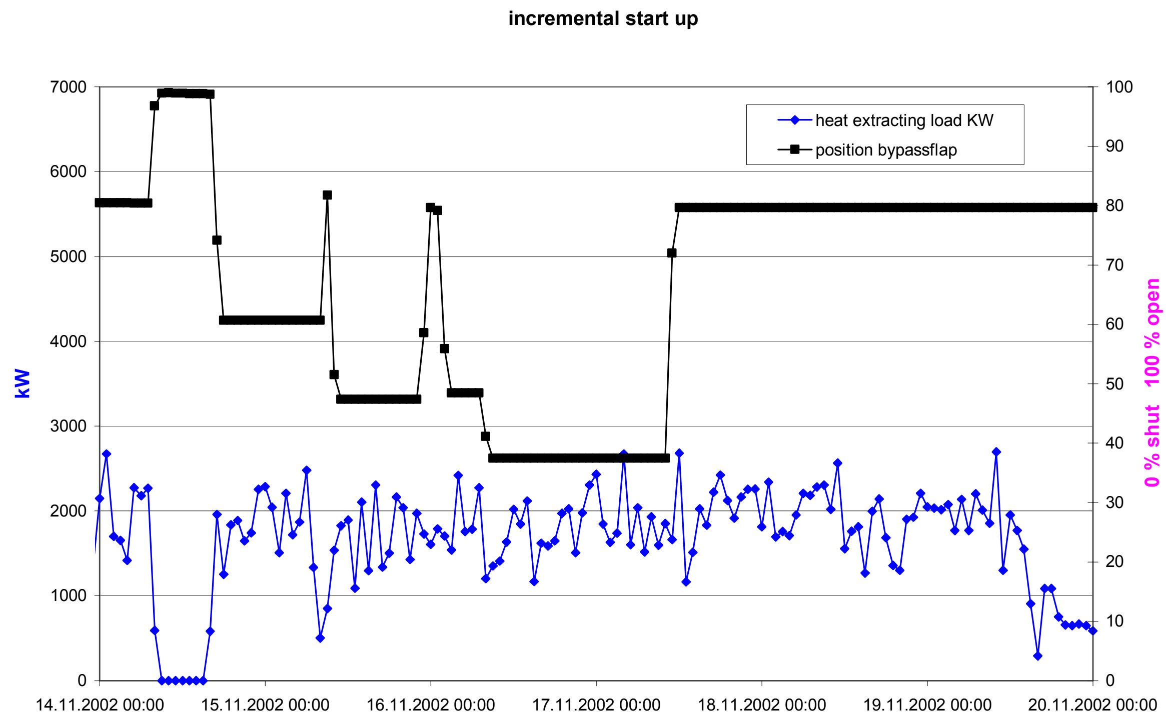
The different thermal expansion of the involved materials (PFA and steel), is compensated by that u. therefore, also lead at big faces for no problems.

The new plant parts were linked with the existing process control system (Metso XD), that has the advantage that every trouble that would be able to damage the operation of the recovery line, will from the staff be recognized immediately. So the staff is able to implement all measures to protect the own operation with priority,

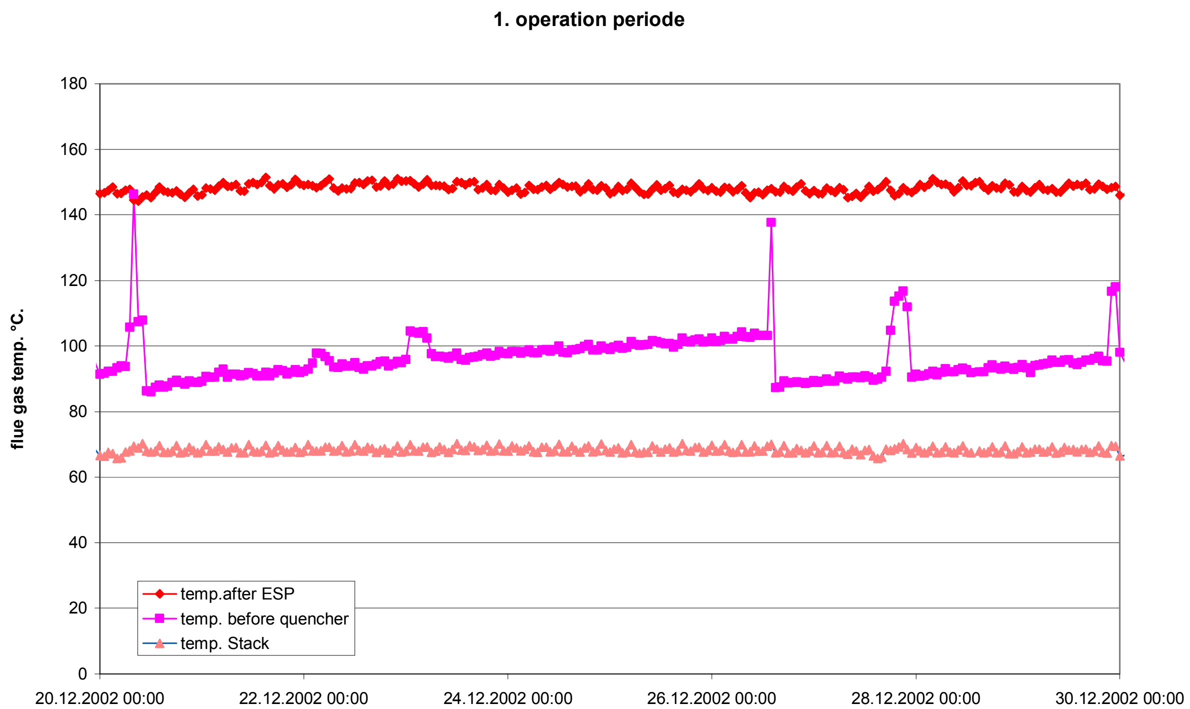
The rebuilding of the installation took place in the mill autumn down time 2002. The commissioning of the installation started after completion of the isolation, integration of all additional aggregates, as well as the measuring and control technology performance, beginning of November 2002.

The first measures and resulting temperature modifications and heat extraction load show the next two diagrams.

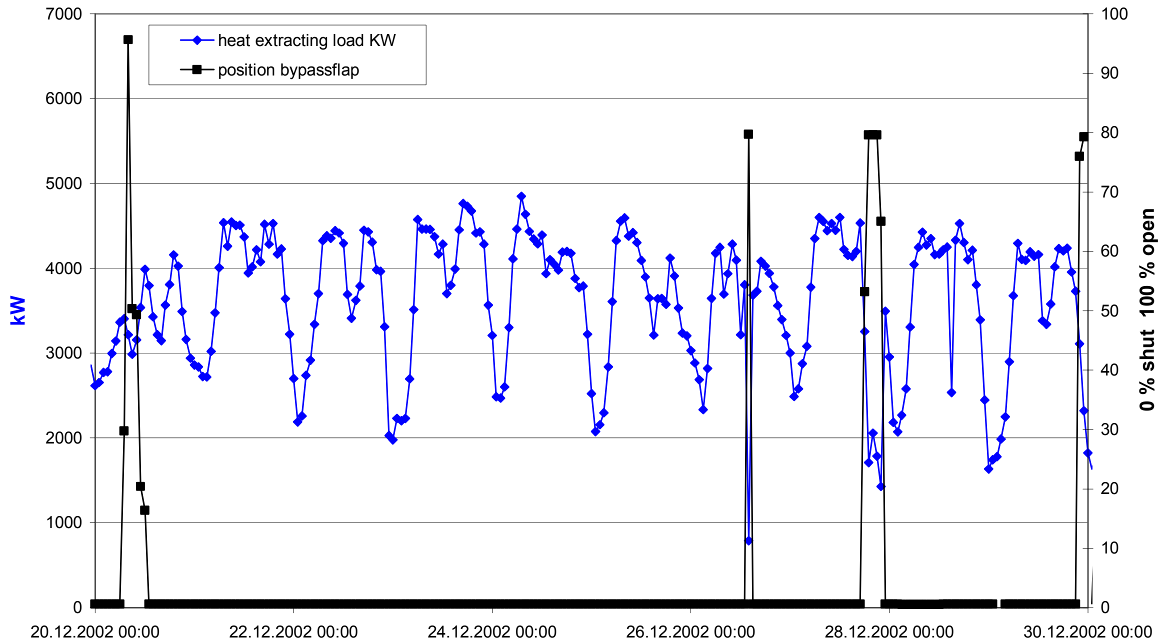




The operating data after implemented optimization. One recognizes that the nominal thermal capacity is already achieved but not yet optimized. Because of irregular cleaning cycles we got temperature rises by pollution of the heat exchanger.

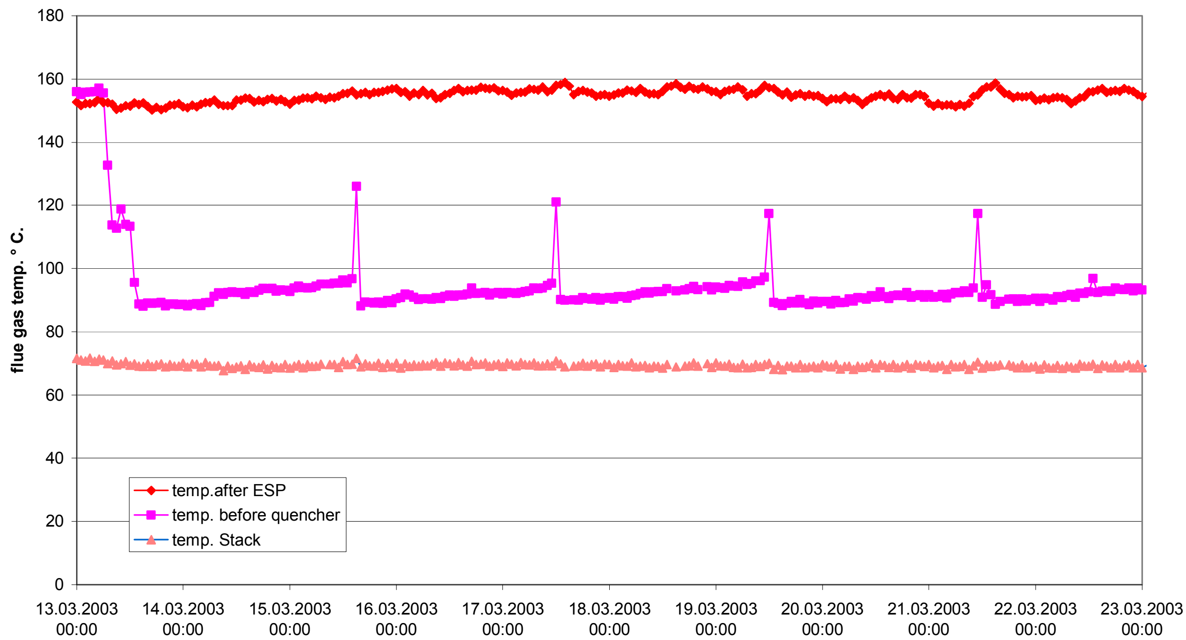


1. operation periode

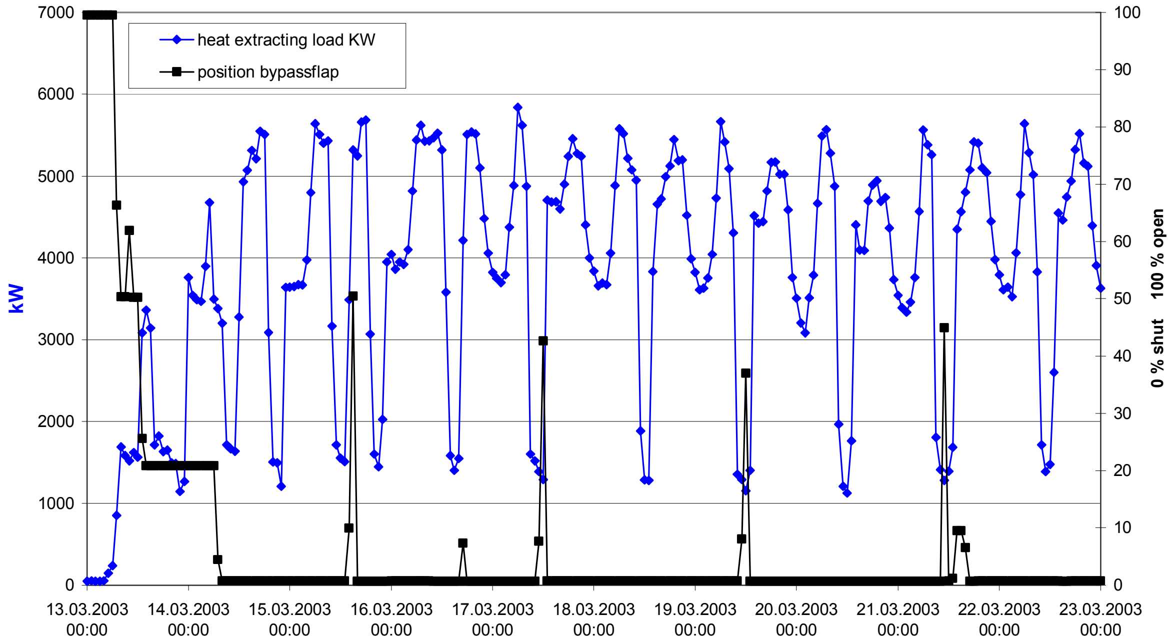


The next data show the performance after elimination of the last lack points in the spring revision 2003. One recognizes acceptable temperature variations and heat extraction loads are above the rated output.

after 1. revision

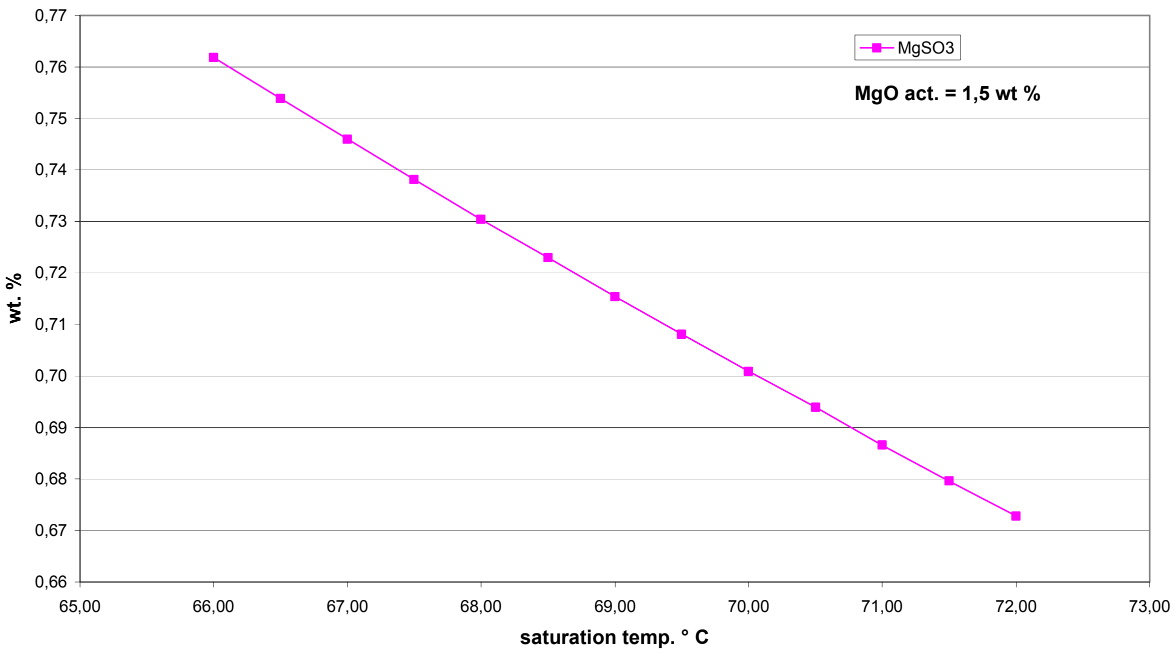


after 1. revision



The drop of the saturation temperature also has advantages in the operation of the raw acid generation stage .because, either in the case of const. MgO content of acid a reduction of mono sulfite concentration is possible and/or if required the MgO content can be increased at the same sulfite level.

MgSO3-conversion f(saturationtemp.)



Respecting long time behavior of the applied technology, no statement can still be made on the basis of the relative short operational experience of course, but that the implied project goals are reached without negative effects on the operation of the liquor recovery boiler and desulfurization and acid preparation plant, can already confirmed after almost 2 business years. To put it in a nutshell, there is a considerable advance with reference to better utilization of the used primary energy and also a significant reduction of environmental burdens in the heat service area, had been achieved.

.

• Extractable heat-load 3,8 MW		
• Oil-equivalent / Gas-equivalent	340 / 429 kg/h / Nm3/h	
• Heat supply of	190 to 475 one family houses	
• Avoidance of air pollution	HFO	NG
• SO_2 – charge	11,6	0 t/a
• NO_2 – charge	5,1	3,7 t/a
• CO – charge	2,9	2,7 t/a
• CO_2 – charge t	8773	7321 t/a
• Avoidance of fuel transportation		

Since the start up, the installation stand in continuous operation and round 26 GWh heat had been extracted until now. This amount is equal 2283 t HFO (heavy fuel oil) resp. 2,6 Mio m3 NG (natural gas).

Biomass CHP Plant with extended flue gas heat extraction

Due to the good experience with the above mentioned project and because of the defiances in connection with Ökostromgesetz, Abfallwirtschaftsgesetz u. green house gas reduction we are going to proceed the adopted way and to realize a 30 MW th biomass plant with a heat extraction part up to 5,85 MW and with a heat transformer up to 7,2 MW.

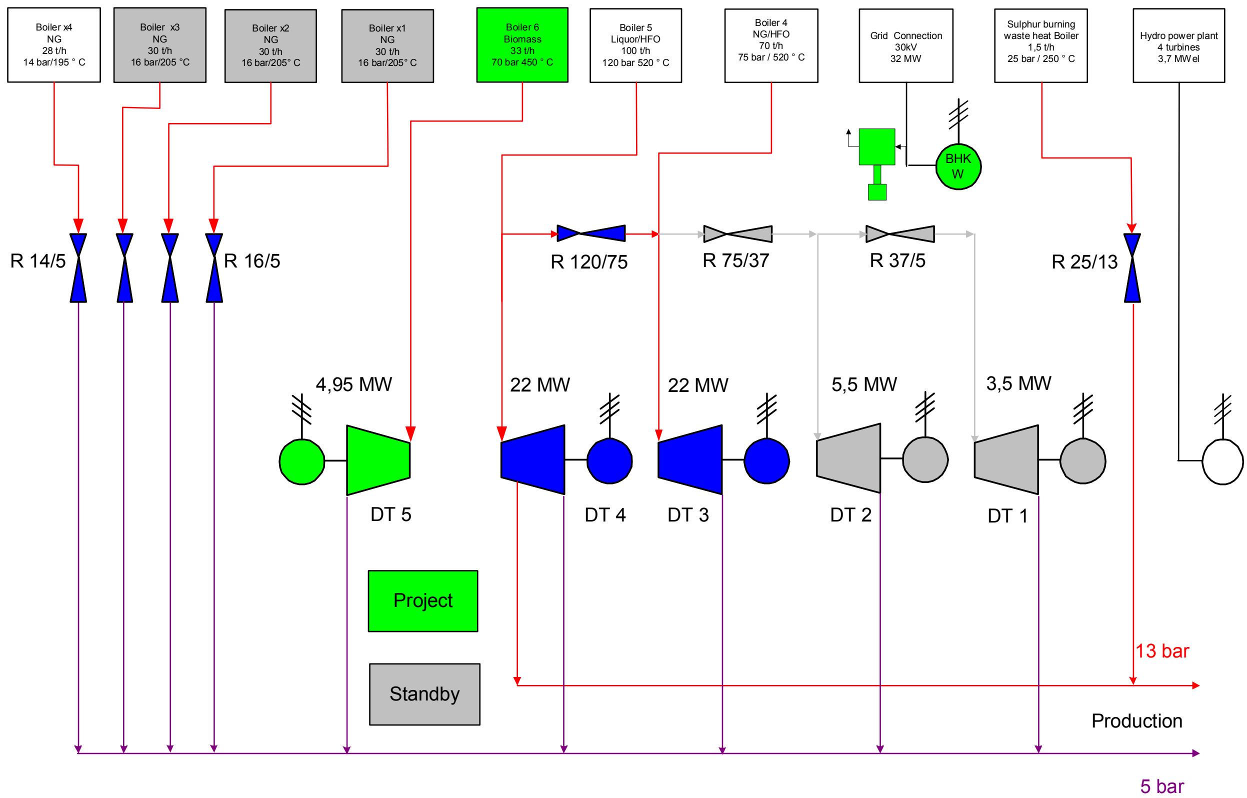
The decision to realise the project was made on the 8th of April 2004, now realisation is going on and commissioning of the plant has to be ready latest in June 2006.

Reasons to build the Biomass CHP plant:

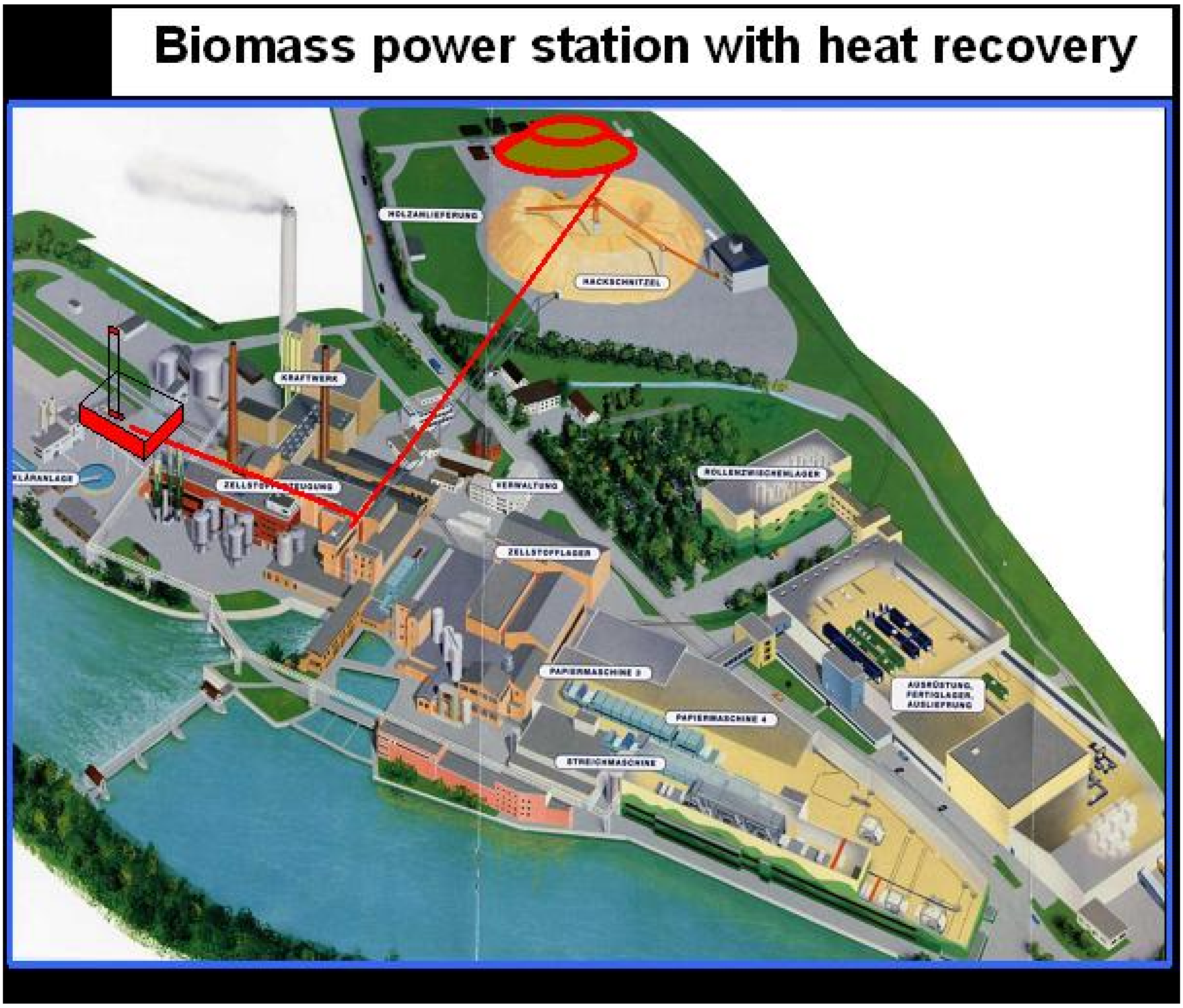
- Best utilization of the arising internal residues
- Reduction of landfill demand (new strict law... Abfallwirtschaftsgesetz)
- Saving the mill steam demand with renewable energy sources
- Substitution of inefficient provisional steam generators (packaged boilers) by a co-generation plant
- Reduction of expensive fossil fuels (~ 16 Mio Nm3/y NG)
- Utilising of state subsidy for green power delivery
- Improve the mill reputation by delivery of district heat
- Long time financial effect by refund of waste heat
- Fulfil the CO_2 saving targets of Austria (13 % basis 1990) for the mill
- Utilizing grants for the plant (BMHKW) investment (up to 5 Mio €)
- Utilizing grants for the heat recovery investment (up to 1,6 Mio €)

The integration of the new biomass boiler in the existing supply structure is shown in the next diagram.

Energy flow diagram from 2006



The location of the new plant is in the area of all the energy and utility devices, to benefit synergy in operation and maintenance. The same philosophy lead to the Integration of the wood handling and processing on the existing wood yard for the pulp production.



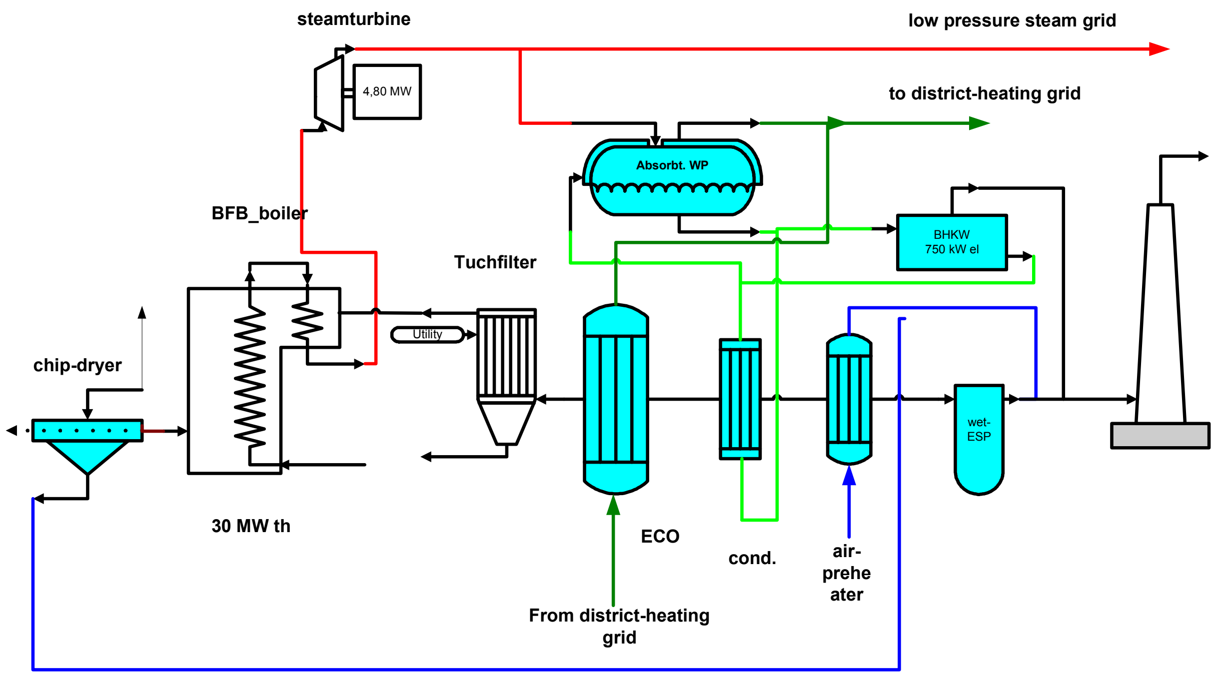
Byside this features for the purpose of the above named reasons the project is supplemented with the following equipments and characteristics. This part of the project is financed and realized through the district heat – Ltd.

Heat recovery part:

- Block heat and power plant for the biogas out of the waste water treatment plant with roughly 850 kWh el. capacity
- Economiser for direct district heating extraction
- Condenser as district heating pre stage
- Absorption heat pump for temperature level increasing on district heating state
- Air pre heater to generate warm air required in wood chip drying and flue gas vapour reduction
- Horizontal belt dryer for wood chip drying
- Wet electrostatic precipitator for aerosol (blue haze) reduction
- Partial vapour reduction in the exhaust gas of the biomass plant

- Construction of a connection between the district heating networks of Hallein and the city of Salzburg

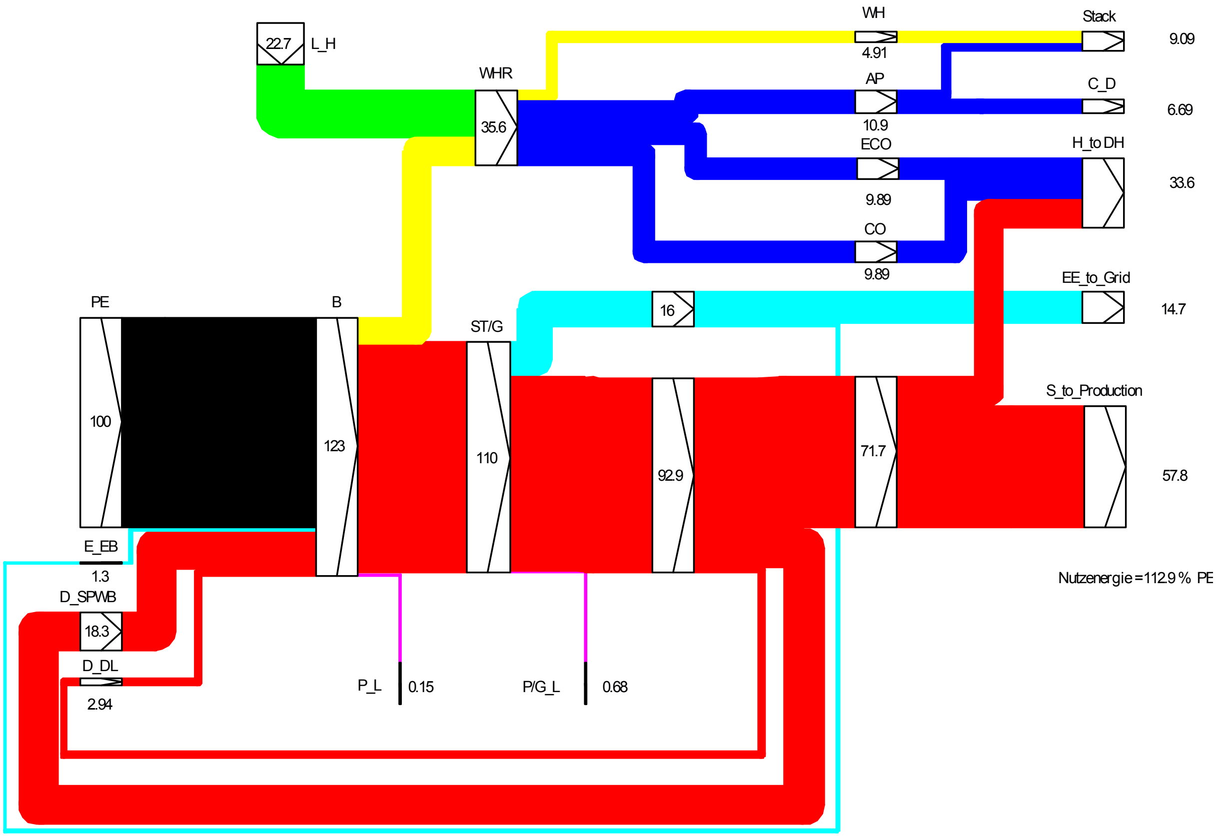
The next diagram shows the flow chart of the hole plant:



The characteristics of the plant are included in the following table:

• Rated power	30 MW th ➡ ~36 t steam/h
• Steam pressure	61 bar
• Steam temperature	450 °C
• Total fuel demand	~15 t/h
	of it wood chips ~10 t/h
• Boiler running hours expected	8520 h/y
• Green electricity production:	
⇒ El. Power steam turbine	4,84 MW
⇒ Annual electric work	48 GWh/y
• Heat recovery for district heating	3,0 bis 7,2 MW
• CO2 avoidance	47000-56000 t/y
• Total project costs of the biomass CHP plant	35,8 Mio €
• Costs of the heat recovery part	6,0 Mio €
• Costs of the district heat grid enlargement	7 Mio €

In the following sankey diagram the energy flow is displayed. Roughly speaking 113% of the inserted primary energy (related to the lower heating value) can be converted into useful energy due to the waste heat recovery.



Summary

At least the background why this heat recovery projects are, respectively will be realized, despite that the cost effectiveness is below the limits of our group and probably the total line of business.

M-real permits the local district heating supplier to integrate all necessary machinery on the premises of the mill. As well the partner get the heat as far as they meet the break even point for their investment without of charge. The partner can also use all mill infrastructure at cost price and pays after the pay back period for the extracted heat only the cost equivalent of the cheapest in Hallein used fuel.

To address the issue why we are acting so, I can assure it is only to support environmental friendly energy and to improve the image of our branch and our site.

Parallel session
Innovative energy efficiency examples of different industrial sectors -
Energy efficiency in pulp & paper and sugar industry

INNOVATIVE EXAMPLES OF ENERGY EFFICIENCY IN GERMAN SUGAR INDUSTRY, ESPECIALLY DE-WATERING FROM SUGAR BEET PULP

Christian Voß
Südzucker AG, for the German Association of Sugar Industry
(Chapter 1 to 2.1.5)
Dr. Joachim Wieting
Umweltbundesamt Berlin
(Chapter 2.2 to 4)

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ABSTRACT

The German sugar industry has reduced its energy consumption about 40%. This positive development has been documented in the statements regarding climate protection.

The total energy consumption during the sugar beet campaign is distributed to approx. 2/3 for the production of sugar and to 1/3 for the drying of pulp.
During the extraction of sugar from sugar beets, extracted cossettes occur as by-product during the aequeous extraction of the sugar beet slices. These come into the market mainly dried as animal feed.
The dewatering is done during two process steps - mechanical and thermal dewatering.
Whereas during the mechanical dewatering only electric energy is needed, the thermal energy is preponderant for the evaporation of water.
The mechanical dewatering is the most effective when done with presses and needs only 1 to 2% of the energy consumption of thermal dewatering. The positive development of the press technology from 1980 until today, which resulted in a reduction of the energy consumption for thermal dewatering of about 25%, is being recorded.

Besides conventionally arranged installations in Germany like high temperature and low temperature drying, steam drying is being used in case of missing drying capacity. Whereas the drying medium in the high temperature and low temperature drying consists of a mixture of furnace gas and flue gas of the steam generator or heated air, the steam drying uses the superheated steam after a steam turbine for the drying process. This results in a reduction of the production of electricity of the live steam. This disadvantage should be avoided on a prototype of the steam dryer, which has been in operation in Groß Gerau from 1985 to 2000. In this dryer steam with a pressure of heating steam for the evaporation station was used. Only when the fluid bed drying was available at then end of the 1980s, an important step towards reliability of operation was reached at the steam dryer.
In an energetic examination of the described examples of installations it is shown that by the operating of the pulp drying according to the principle of the steam drying, the sum of energy consumption and fuel energy is the lowest. With the use of the latest process in Germany for the time being, both less energy is consumed and less total carbon and dust is emitted. Due to the high investment costs, the change-over from conventional processes to the modern drying by evaporation can only be expected by a basic modernisation of the installations or by the new erection of a sugar factory.

1. Introdoction

(Targets and development of the specific energy requirement)

The German Association of Sugar Industry is in favour of further development of the 1996 declaration with which German industry took on an obligation to take precautionary measures in the interests of the climate. For this reason, the German Sugar Industry Association actively supported the negotiations leading to the "Agreement between the Government of the Federal Republic of Germany and Germany Industry on Precautionary Measures for the Climate" signed on 11th November 2000 and became a member of this general agreement in that year.

With this new general framework agreement and in view of the targets set in the Kyoto Protocol, German industry undertakes to reduce their specific CO_2 emissions by 28 % by 2005 and their specific emissions of all six Kyoto gases by 35 % by 2012 (in comparison with 1990 and related to the whole of Germany in each case).

Declarations made by individual sectors of industry may, depending on their individual circumstances, either fall short of or exceed the general agreement. As regards their "special efforts to take precautionary measures in the interests of the climate", the German sugar industry has seen their way to making a declaration regarding their specific CO_2 emissions which promises a reduction of more than 35 % (the other greenhouse gases in the Kyoto protocol are of no significance in the sugar industry).

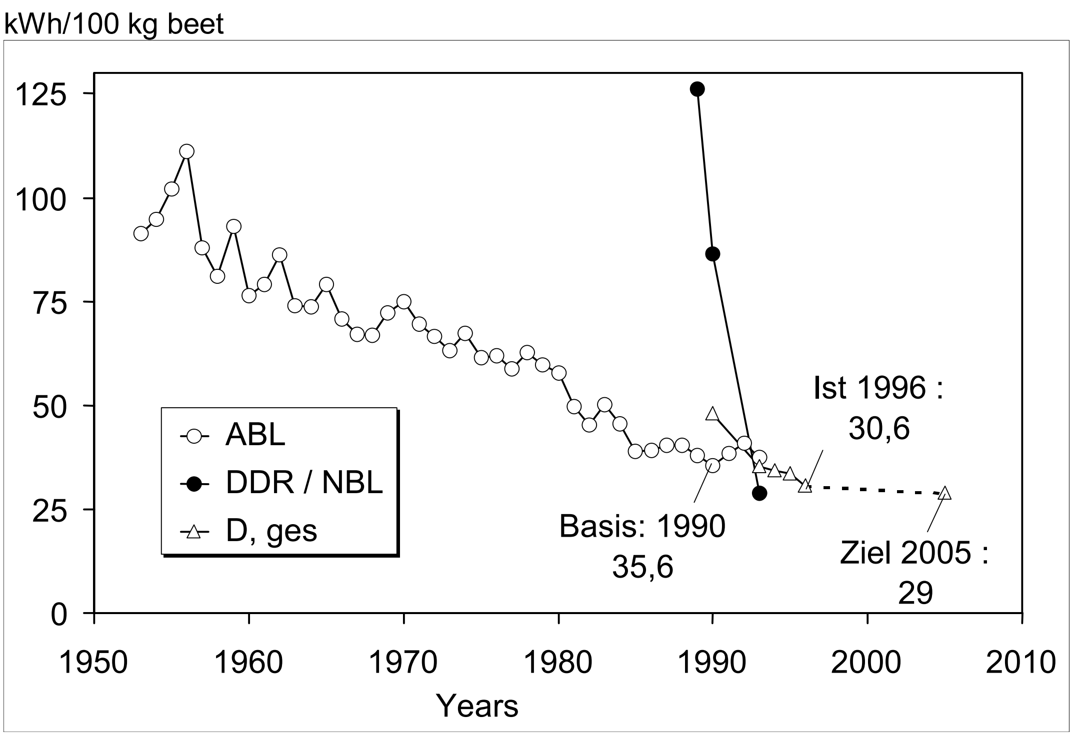
On the basis of this general declaration, the German Sugar Industry Association, in a declaration made for the sugar producing sector on 19th December 2000, promised a reduction of the CO_2 emissions specific to the sugar industry of between 41 and 45 % in comparison to 1990/91. This will mean a reduction in the specific CO_2 emissions from 148 kg/t beet in the base year to between 81 and 87 kg/t beet in 2005/06.

Tab. 1: Energy Management Report

Years	**Details per tons of beet**	
	spec. CO_2	**spec. energy**
1998	94 kg	314,9 kWh
1999	85 kg	304,6 kWh
2000	84 kg	288,5 kWh

In the years 2001 – 2003 energy consumption and CO_2 emissions have continued to improve.

The degree of target achievement is almost 100 % and is exemplary.



ABL: Federal Republic of Germany

DDR/NBL: German Democratic Republic/New Federal States

D, ges: Germany, total

Fig. 1: Specific Energy Requirement in the Sugar Industry (kWh/100 kg beet)

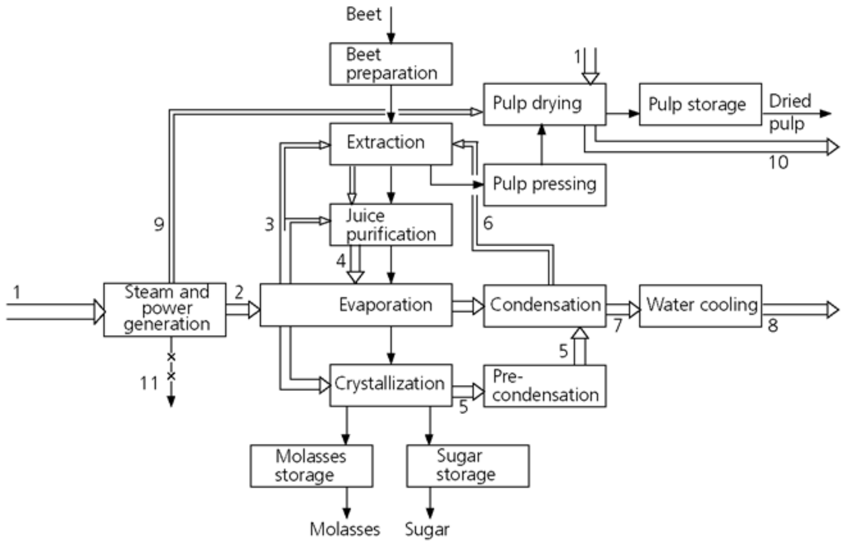
Fig. 1 documents the long-term development of energy requirements in German sugar industry from 1953 until 1996, including weather and growth related fluctuations. Thus, for example, the specific energy requirement in 1992 in the states of the old Federal Republic of Germany (40.78 kWh/100 kg beet) was higher than the corresponding value for 1987 (40.42 kWh/100 kg beet) and both figures were higher than that of the base year, 1990. The illustration also shows the reduction trend of the specific energy requirement which follows the laws of physics and is of necessity asymptotic overall. The black dotted line shows the specific energy consumption of the sugar industry from 1989 until 1993 in what was formerly the German Democratic Republic and then became the new states of Germany. This figure dropped considerably due to reunification. As a result of these different developments in the East and West German sugar industries and due to the uncertainties of official statistics following reunification, the specific energy requirements of the East German sugar industry were not taken into consideration in the base year 1990 or through to and including 1993.

Not until 1994 was the energy requirement recorded for the whole of Germany (This graph showing the energy requirements for the whole of Germany from 1990 is shown here merely for documentation purposes.).

The energy savings achieved since 1990 were obtained by considerable investments amounting more then 300 million Euros, combined heat and power (CHP) efficiency factors of around 90 % being the rule. Decision making was seldom motivated by business management arguments alone, but rather by the realisation that the best environmental protection measures are those which save energy. The rule is that not burning primary energy is the best way of protecting the environment.

N.B. from Mr. Voß: This preventative environmental protection used to be provided on economic grounds by the planning control within the sugar market regulations (ZMO). Without sugar market regulation we are no longer able to guarantee that. The fact is that at world market conditions, e.g. in Brazil or Thailand, sugar is produced without environmental protection and causing, of course, many times more damage to the environment than in Western Europe – the term “European environmental standards” is completely unknown there.

The saving of primary energy in the sugar industry is restricted by the physical limits of the energy requirements for the technical processes. The sales products of the sugar industry are almost 100 % solid matter. The water from the sugar beet and also the water used in the processes has to be evaporated. When sugar is produced from sugar beet, approximately 7 kg water have to be evaporated for each kg sugar. This makes the sugar industry one of the most energy-intensive procedure technologies. Energy saving has always been a big issue, using the possibilities of combining heat and power. Thus the multiple use of heat with a factor >7 is normal in the German sugar industry today. Any further increase of this process will be increasingly complicated in technical terms and will only produce marginal energy savings.



Main energy: 1 Fuel, 2 Steam, 3 Vapours, 4 Hot Juice, 5 Evaporating crystallizer vapour,

6 Hot water, 7 Condenser water, 8 Heat dissipated to the environment, 9 Flue gas to pulp drier

10 Gas from pulp drier exhaust, 11 Power

Fig. 2: General presentation of sugar production from sugar beet and energy conversion in a sugar beet factory

No other industry has such a large number of technical processes which are so closely linked to each other.

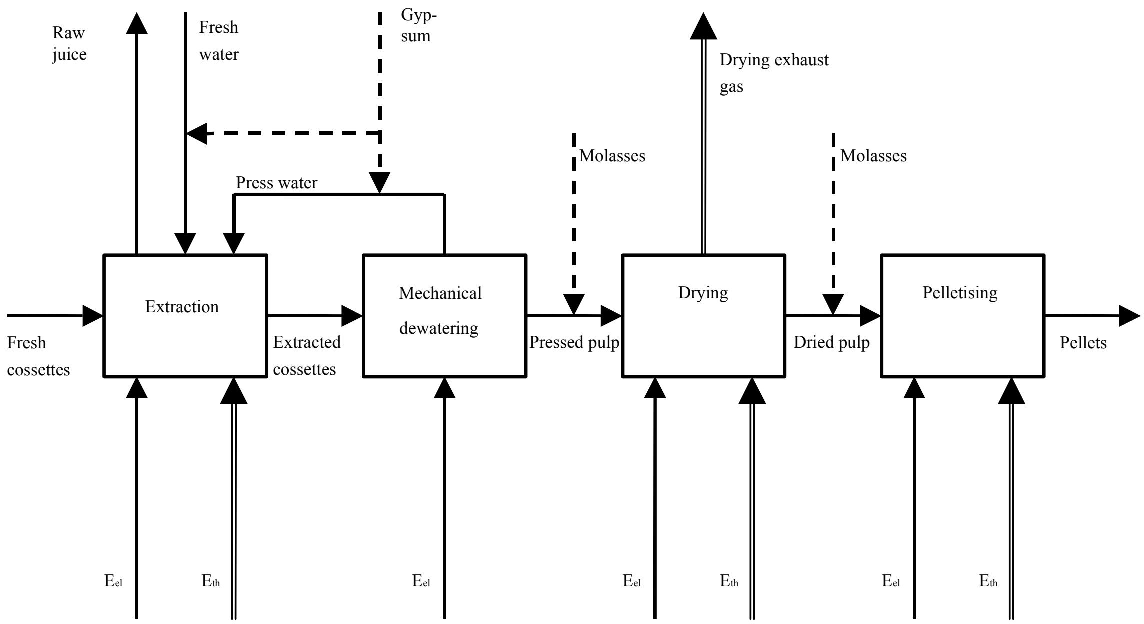
The ratio of the energy used for producing sugar and dried sugar beet pulp is approximately 2 to 1.

In the following we want to concentrate on the dewatering of sugar beet pulp, because my colleague from Austria is going to focus on sugar production (and much of what he will have to say applies equally to the German sugar industry). The other reason is that the first print of VDI Guideline 2594 – "Emission reduction in pulp drying plants in the sugar industry" - have now been completed. Specialists from the fields of science, industry and administration have worked out the state-of-the-art (best available technology) in Germany. The guideline serves as an aid to decision making when working through and applying legal and administrative regulations. The results of this project also become a part of the joint German position for the European technical documents regulations. It has had a direct influence on the European development of the **B**est Available Technique **Ref**erence-Documents (BREF) on "Food, Drink and Milk", which has been compiled at the European **I**ntegrated **P**ollution **P**revention and **C**ontrol (IPPC) Bureau in Seville/ Spain. Dr. Wieting of the Federal Environmental Agency in Berlin and I have also worked on VDI Guideline 2594 and have therefore been authorised to present it to you together.

2. Dewatering process for sugar beet cossettes in the sugar industry as regards energy

When sugar (sucrose) is obtained from sugar beet, during the water extraction process, extracted cossettes result as a side-product with a mass water content between 83 and 90 %.

Due to its durability and the reduced freight costs, dried pulp is usually marketed in pellet form. The main steps of the procedure for producing dried animal feed are shown in Fig. 3. The cleaned beet are sliced into fresh cossettes in the slice machines and are then conveyed to the extraction process.



Eel = electric power, Eth = thermic energy

Fig. 3: Steps of Procedure for Obtaining Dried Pulp

2.1 Primary mechanical/thermal extraction

In order to keep energy consumption for drying low, the target is to reduce the quantity of water applied by pressing the extracted cossettes out mechanically as much hard as possible. In table 2 the quantity of water to be evaporated is shown in relation to the various solids contained in the pulp.

Tab. 2: Dependence of the to evaporated water quantity to the dry substance content from the press pulp

Solids contained in the pulp (before drying)	tons to evaporated water quantity per ton dry pulp	relative difference of the water loading
	(1)	(2)
%	t	%
25	2,60	+47
30	2,00	+13
32, 5	1,77	
35	1,57	-11
40	1,25	-29
45	1,00	-44
50	0,80	-55
55	0,64	-64
65	0,38	-79

(1) Tons to evaporated water quantity to each 1 ton of dried pulp with content of dried substance in the dried pulp of 90 %

(2) Relative difference of water loading in relation to the content of dried substance in the press pulp with 32,5 %

The production of dry pulp is shown without consideration of the specific energy consumption in simplified terms the plus difference as energy-more-consumption and the minus difference means energy-less consumption.

At this time the target from a German sugar factory with pulp drying is to reach a dewatering with a content in press pulp of 32,5 %. This is the result and its shown in the column two.

2.1.1 Mechanical Dewatering

The first stage in drying the extracted cuttings is carried out in screw presses only. Other systems such as a band press have proved to be not so efficient. Fig. 4 shows the working principle of a horizontal snail-shaped press.

pulp inlet

screen

ring, axial relocatable to the

pressing pressure variation

press water collector

pulp outlet

Fig. 4: Drawing of a snail-shaped press with a conical spindle and a diminishing thread

The material being pressed is pushed along and cut. The water is taken off along the cylindrical cover and also in part along the spindle through sieves. The less cuttings are fed through, the greater is the solid matter content obtained, depending on plant capacity. Single and double spindle presses are the types most commonly used – volume must be reduced through the press to build up the required pressure. The pressing process can be optimised by lacing the pulp with calcium ions. Within the normal range of solid matter content (30 % to 35 % - water content 65 % to 70 %) gypsum is added in a ratio of between 0.1 kg/100 kg beet to 0.17 kg/100 kg beet. The physical limits of mechanical pulp drying with spindle presses are dictated by the state of the art (top values are around 36 % solids). Torque is high and the drives of the pulp presses are subject to critical mechanical loads.

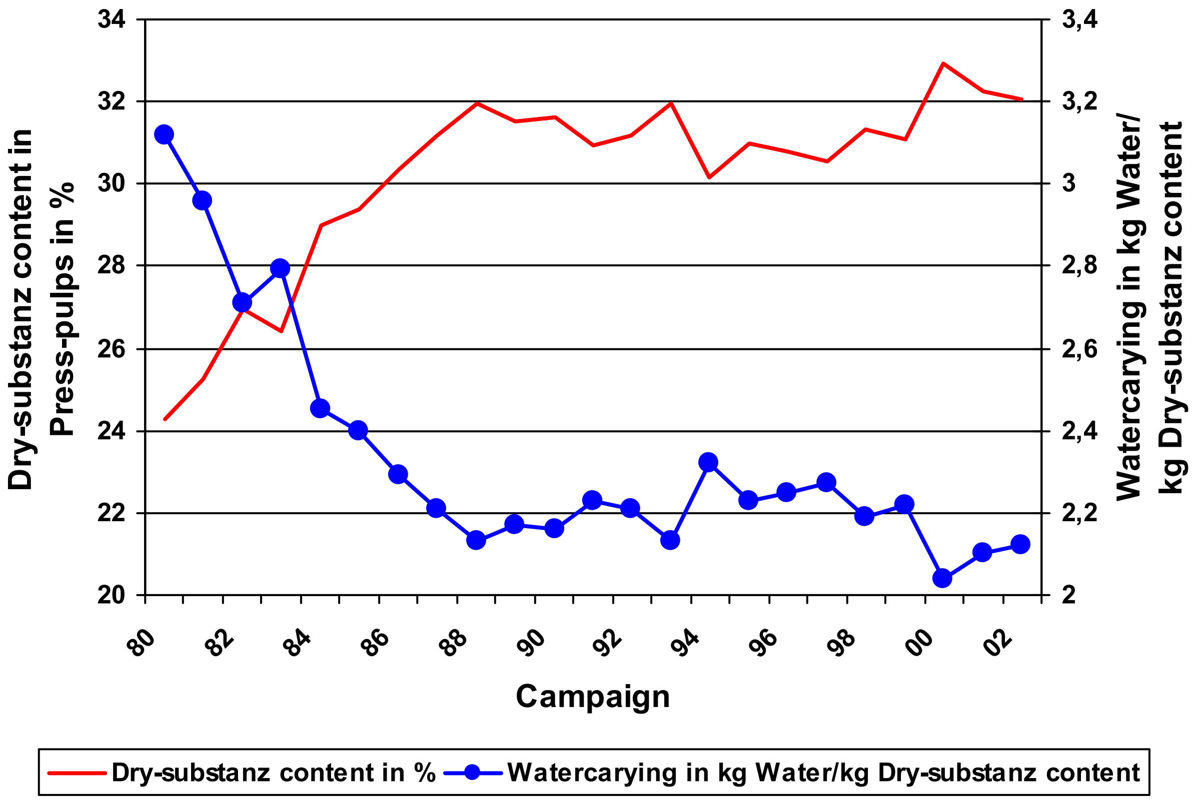


Fig. 5: Development of mechanical drying from 1990 – 2002 at Südzucker with pulp drying plants

At 30 kWh/t water, the energy used in mechanical drying is only about 1 % of that used in the subsequent thermal drying process – approximately 3.000 kWh/t water, and so Südzucker concentrated investments in new mechanical drying technologies and plant and ran large-scale technology tests. Südzucker tested in large-scale technology:

2.1.2 Diffusive Dewatering

On the basic of a SZ-patent the diffusive dewatering have be reached the practice maturity on the place of Ochsenfurt.

Fig. 6: Scheme of the method of diffusive dewatering

Fig. 7: Scheme of the diffusive dewatering plant

Mixing **Squeezing** **Evaporation**

Stordpresse

Steam after
Turbine

Low pressure
Steam

Juice separator

Molasse

Press
DK 2500

Condesate

Drying

Extracted, pressed cossetes are mixed with molasses with a high solid matter content. The mixture has a porridge-like consistency and is then dried in a conical press. The water separated off in this way can be evaporated from the pressing liquid in the evaporating plant with low-pressure vapours and the pressing liquid is thus concentrated. The aim was to produce storable animal feed with a high sugar content and 65% solid matter content based on the conserving effect of molasses. The drying process is no longer necessary and the product is produced without emissions. The product can later be dried and normal dried pulp pellets with added molasses produced, in which case the energy saving could be around 70%.

Of the machines available for separating solids and/or liquids from the difficult mixture of pressed and molasses, the conical press proved to be the most suitable in the preliminary trials. However, we could not keep the press under control in permanent operation, so that the process in Ochsenfurt was discontinued.

2.1.2 High-pressure, multi-layer pressing (HMP)

In Regensburg high-pressure, multi-layer pressing - hyperpresses - were tested on a large-scale. This press was intended for use as a “strait jacket“ press with hermetic edge seals and, once approved, as a further development for diffusive drying.

Technical Data of the HMP:

Total weight of the machine		approx. 680 t
Dimensions:	Length	approx.. 50 m
	Width	approx. 6 m
	Height	approx. 7.5 m
Filterband width		2.0 m
Layers of cuttings		20

Thickness of layers (adjustable)		20-30 mm/layer
Length of pressing line	2 x 23 m =	46 m
Hydraulic pressure can be regulated		up to 350 bar
Pressurecan be regulated		up to approx. 1.000 N/cm^2
Pressing time	can be regulated	15 min
No. of pressing cylinders in the line		384
Length of the filter bands		95-110 m

(1) Application of pressure, (2) Pressing layers, (3) Pressed water

Fig. 8: Principle of the procedure:

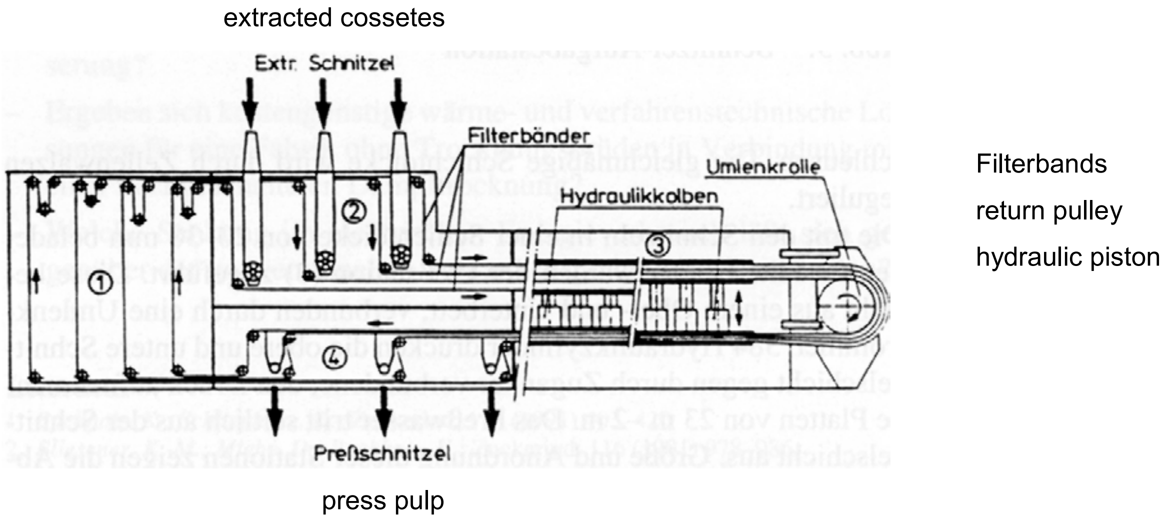


Fig. 9: Scheme of the HMP type Regensburg

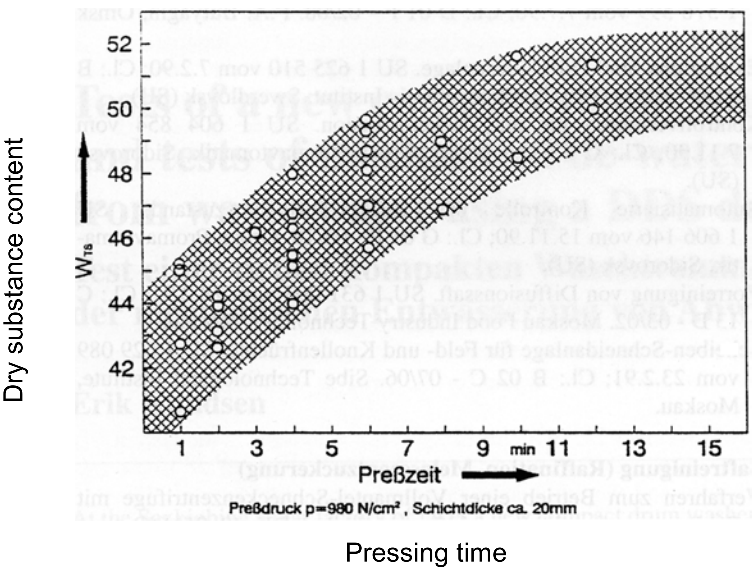


Fig. 10: Capacity of dewatering from the HMP type Regensburg

Extracted cossetes are placed at intervals on circulating endless cloths by means of distributor screws, transported to the pressing plates and pressed out. The press works with a pressure of 100 bar and has 20 cloth bands and makes very special demands on the quality of the cloth. The through-flow of cuttings corresponded to processing 2400 tons of beet per day. In „permanent operation“ it was possible to achieve 50 % solids in the pressed cuttings. 1 load took 5 to 10 minutes to press. Despite high expenditure on scientific personnel and other costs we were forced to discontinue the procedure. It was not possible to keep the quality of the cloth and >300 hydraulic control loops under control.

We shall take up the idea of diffusive drying again when it is possible to separate solids and liquids with suitable machines.

2.1.4 Extraction under alkaline conditions

Fig. 11: Pilot plan scheme for pressing of alkaline treated cossetes

Trials were run using calcium in a pilot plant with a through-flow of 1 t/h in Warburg in co-operation with the Sugar Institute in Brunswick from 1986 until 1988. When pressing out the cuttings extracted under alkaline conditions it was possible to achieve >45 % solids. However, due to several unsolved technical problems with the existing presses, it was not possible to continue with the project. Alkaline extraction in France and England suffered a similar fate.

2.1.5 Electroporation

Südzucker is hopeful that electroporation of whole beet in water (cold extraction) with subsequent alkaline treatment of the cuttings will be successful. Conventionally the beet cells are opened up by heat, in electroporation by setting up an electrical field. The cell membranes are opened by high-voltage impulses with a voltage of several hundred kV for 1µsec. The electrical energy requirement for 1 kWh/t beet is very low. Fig. 12 shows the effect of electroporation. The beet thus treated is glassy and the juice flows out. Cutting is an easy job. The cuttings are highly elastic, see Fig. 13, but will still stand up to a high mechanical load. This guarantees that they can be pressed out well.

Electroporation prepares the pulp for increased acceptance of calcium ions in alkaline extraction. As a result the extracted cuttings can be pressed out to 40 - 45 % solid matter on average. The principle can be seen in Fig. 14.

The trials have been running for 2 years in Offstein and are promising. Our problem is that we can only work in the season and lose 2/3 of each year. For this reason technical trials on a large-scale will not be possible before 2006.

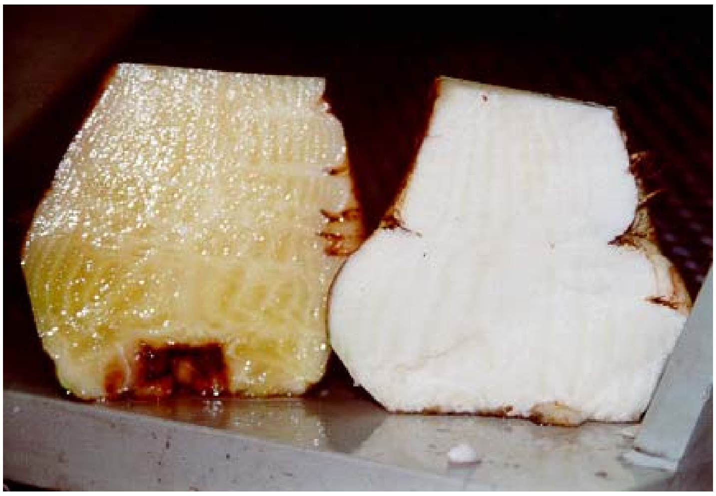


Fig.. 12: Two sugar beets half in relation:left side is electroporated, right untreated

Fig. 13: electroporated cossettes are very flexible and have a high mechanical loading capacity

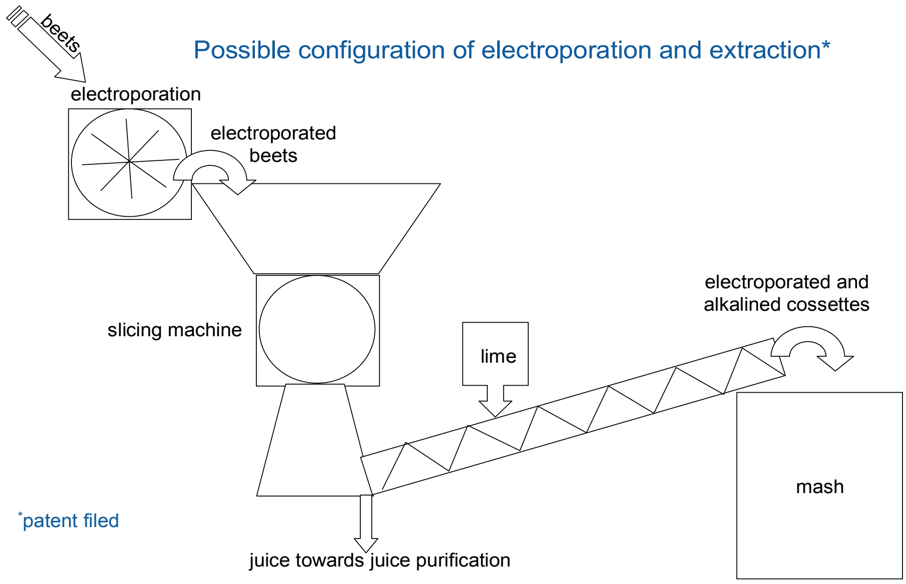


Fig.. 14: Principal scheme of elektroporation

There are two energy saving effects

- With the same yield of sugar, the procedure requires 20 % less juice extraction (= less thinning) with a correspondingly lower steam requirement for heating the juice, pressing and crystallisation.

- We want to achieve 45 % solids in the pressed cuttings which would mean a 40 % energy saving in the subsequent drying process.

2.2 Drying processes

2.2.1 Pulp drying process

Two processes are considered for drying:

- The first process is known as low temperature drying (LTD). The required mass and volume flows of drying gas are extremely large. For this reason, chips and drying gas are introduced in transverse flow during this drying process (apparatus: belt dryer). The dwell time of the chips is therefore not dependent on the speed of the drying gas. Due to the low temperature and the comparatively high relative humidity, the propulsive forces and water absorption capacity of the drying gas are too low to dry the chips to equilibrium moisture content level. This process is therefore only utilised for the first drying phase. The preferential sources of energy for drying are the heat flows of the sugar factory at temperatures of below 60 °C that would otherwise be released into the environment as waste heat.

- The second process is the most frequently used process throughout the world for chip drying in a directly heated granulator, which in contrast to the first mentioned process is known as high temperature drying (HTD). Chips and drying gas are conducted in co-current flow (see Fig. 2.2). Per kg of water evaporation, low temperature drying (LTD) requires approximately the 30fold gas throughput of high temperature drying (HTD).
  Belt dryers, granulators and fluidised bed dryers may be considered for use as drying apparatuses.

2.2.2. Pulp drying by evaporation

The pressed pulp from the chip pressing station is channelled towards Evaporation Dryer 1 or 2 (ED) through transport and metering devices. They reach the first of 16 cells arranged around the super-heater in the middle of the ED over a cellular wheel sluice with a screw conveyor. The steam superheated in the super-heater by the extraction steam of the steam turbine is transported through the perforated base plates of the cells with a fan which is the only moving part on the ED besides the cellular wheel sluice. As a result, the chips are kept in suspension and transported. In this fluidised bed at 3 bar (super-heating temperature of 150 – 180 °C) the evaporation of the water portion of the chips takes place. The heavy particles pass through the open cell walls of cells 1 to 16 in the lower section, whereas the lighter particles are transported upwards into the conical portion of the ED and reach cell 16 over diagonally arranged surfaces and guide rails. The circulated steam is channelled towards the upper portion of the ED structured as a cyclone through guide vanes, in order to separate out the dust particles. These collect at the outer wall of the cyclone and are from there channelled into cell 16 by means of an ejector. From Cell 16 the drying items are discharged into a cyclone by screw conveyors and cellular wheel sluices. From there, the dried pulp reaches a molassing screw through a further cellular wheel sluice for the metering of molasses. The chips are channelled towards the pellet station through a conditioning screw.

The steam extracted from the evaporation dryer has a pressure of approximately 3 bar and is utilised in the process of sugar extraction as the heating steam of the evaporation station. Approximately 2/3 of the produced steam at a pressure of approximately 25 bar is utilised in the ED and converted into process steam of 3 bar. The pressure or enthalpy gradient of between 25 bar and 3 bar can therefore not be utilised for the generation of electrical energy as is usually done in sugar factories. In order to cover the internal demand of the factory, including the high energy consumption of the dryer, a gas turbine with a down-stream steam generator is installed as a waste heat boiler. The boiler is operated with heavy gas oil (< 1% sulphur content) for additional heating. The produced hot steam is channelled towards the down-stream bleeding back-pressure steam turbine. The turbine feeds out the volume of steam required for the heating of the evaporation dryer with a pressure of between 11 and 25 bar. The entire power-heat coupling system, consisting of a gas turbine, boiler plant and steam turbine operates at an efficiency of above 80%. The vapours released in the EDs are utilised further in the evaporation station. The vapours are initially channelled over a down-stream steam converter (SC) for this purpose and subsequently serve as a source of heating for the 1st phase of the evaporation station.

The following figure shows the schematic flow diagram of pulp drying.

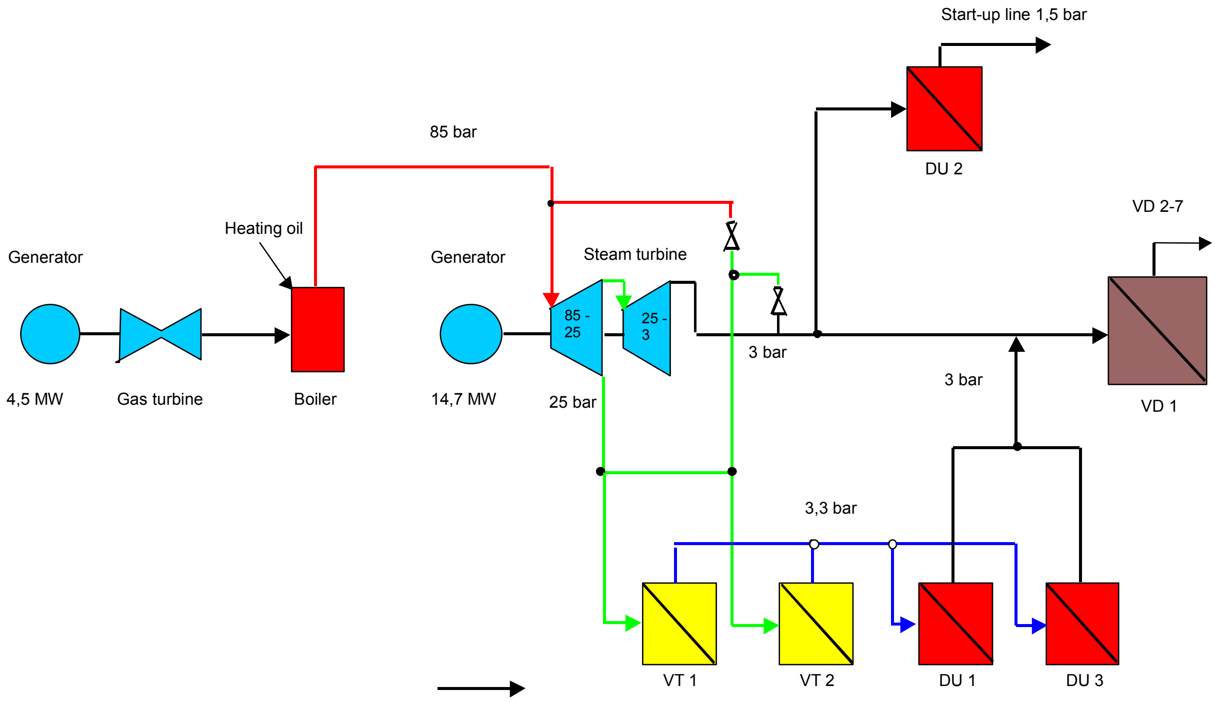
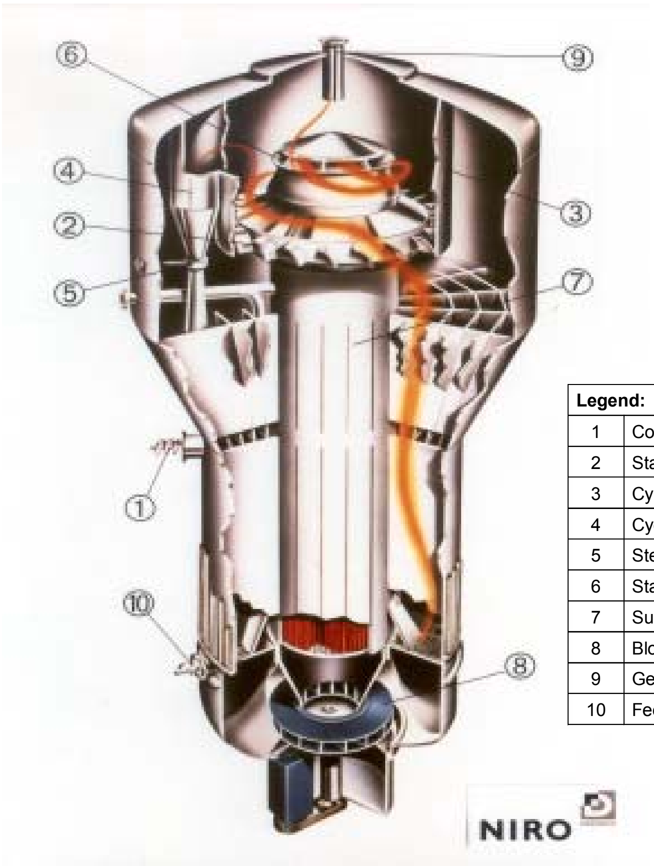


Fig. 15: Schematic flow diagram of the steam system in a sugar factory

The following figure shows the structure of the evaporative dryer.



Legend:	
1	Cossette feed screw in cell 1
2	Stationary guide vanes
3	Cylinder with cyclone effect
4	Cyclone over cell 16 for separating entrained cossettes
5	Steam inlet into cyclone
6	Stationary guide vanes for steam return
7	Superheater for secondary steam
8	Blower fan for creating fluidised bed
9	Generated steam exit
10	Feed screw for cossette output from cell 16

Fig. 16: Diagram of a fluidised bed dryer used for drying sugar beet cossettes

3. Energy efficiency in pulp drying process

For the purposes of energy considerations regarding the three example plants outlined example above, the framework data of the factories are standardised, as follows:

- Beet processing 10.000 t/d
- Campaign length 90 d/a
- Pressed pulp mass flow 160 kg/t beet processed = 66,7 t/h
- Dry substance content of the pressed pulp 31 %
- Dry substance content of the dried pulp 90 %
- Steam demand sugar factory 200kg/t beets processed = 83,4 t/h
- Live steam pressure 85 bar
- Live steam temperature 525 °C
- Thermal value of the fuel 40.195 kJ/kg
- Electric energy demand of the sugar factory without drying 10,4 MW = 24,96 kWh/t beets processed
- Complete crystallisation of the concentrated juice in the beet campaign
- The standardisation also assumes the complete crystallisation of concentrated juice in the beet campaign.
- These standards assume the following technical equipment is used at the plants:
- A steam generator with 85 bar and 525 °C
- A corresponding back pressure turbine
3 bar of back pressure for supplying the evaporator station or
3 bar back pressure and 25 bar extraction pressure for supplying the evaporation dryer.
- A gas turbine for lowering the supply of electric energy during the utilisation of an evaporation dryer
- An effluent treatment plant that is capable of processing the condensate from the vapours of the evaporation dryer.

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		Evaporation dryers	High temperature dryers	Low temperature and high temperature dryers	Factory without dryers
Beet processing	t/d	10.000	10.000	10.000	10.000
Evaporation station steam demand	t/h	83,33	83,33	83,33	83,33
Electric energy demand for drying	MW	1,15	0,80	1,70	0,00
Electric energy demand rest of factory	MW	10,40	10,40	10,40	10,40
Total electric energy demand	**MW**	**11,55**	**11,20**	**12,10**	**10,40**
Specific electric energy demand for beet processing per tonne of beets	kWh/t	27,72	26,88	29,04	24,96
Fuel energy HTD	MW	0,00	44,70	37,67	0,00
Steam generator fuel energy	MW	57,12	67,13	67,13	67,13
Gas turbine fuel energy	MW	16,60	0,00	0,00	0,00
Total fuel energy	**MW**	**73,72**	**111,83**	**104,80**	**67,13**
Steam turbine electric energy output	MW	7,,92	11,66	11,66	11,66
Gas turbine electric energy output	MW	4,00	0,00	0,00	0,00
Total electric energy output	**MW**	**11,92**	**11,66**	**11,66**	**11,66**
Electric energy supply	MW	0,00	0,00	0,44	0,00
Electric energy output	MW	0,37	0,46	0,00	1,26

Table 3: Comparison of energy balances of three different options for beet pulp drying and for a plant without drying

Table 3 shows the data arrived at for the standardised factories with drying plants and for comparison purposes a plant without drying of pressed pulp.

The **electric power** requirements are highest for a factory with a low and high temperature dryer at 12,1 MW. The power requirements with an evaporation dryer are only slightly (5%) lower at 11,55 MW. A factory with a high temperature dryer has electric power requirements of 11,2 MW. The power requirements for the factory without drying is 10,4 MW, so that the following requirements result for the drying process:

- High temperature dryer: 0,8 MW
- Evaporation dryer: 1,15 MW
- Low and high temperature dryer: 1,7 MW

The fuel energy (**thermal energy**) demand of high temperature drying is highest at 111,82 MW, followed by low and high temperature drying at 104,80 MW. The factory with evaporation drying still requires 73,72 MW.

Comparing the total thermal energy need involving drying with that in a plant without drying, the **thermal energy** need for the drying step can be calculated:

- High temperature dryer: 44,7 MW
- Evaporation dryer: 6,59 MW
- Low and high temperature dryer: 37,67 MW

The following values resulted for the supply and output of electric energy:

- High temperature dryer: Output of 0,46 MW
- Evaporation dryer: Output of 0,37 MW
- Low and high temperature dryer: Supply of 0,44 MW

In **high temperature drying**, 40% (44,7 MW out of 111,83 MW) of the total thermal energy demand of the plant is needed for the drying step. The specific thermal energy demand for water evaporation is low (about 3.7 MJ/kg vapour).

For **two stage drying** (low temperature drying followed by high temperature drying), 38% of the water is evaporated in the low temperature drying step but 9.7 times more air is needed in this stage than in the high temperature drying stage. The low temperature drying has a higher specific energy demand. The 34 MW thermal energy demand in low temperature drying represents about 7 MJ/kg vapour specific consumption, while the 41 MW in the high temperature drying gives about 5.2 MJ/kg vapour specific energy consumption.

In **fluidised bed drying**, only 6.59 MW is needed for drying out of a total thermal energy consumption of 73.72 MW. When the application of co-generation, the electrical energy balance of the plant is positive, that is 0.37 MW more electricity is produced (output). Although a considerable portion of the steam hat is outputted by the back pressure turbine at approximately 27 bar is not fully available for conversation into electrical energy.

3.1 High temperature drying

Fig. 17 provides a flow chart of high temperature drying. The actual drying process, vaporisation drying, takes place in a drying drum. The molassed pressed pulp is channelled towards the drying drum and is passed through the drying drum in co-current with drying gases. The dried pulp leaves the drum on the opposite side.

A mixture of furnace gas and flue gas from steam generation is utilised as drying gas. A small portion of the drying gas is formed by so-called "leak" or cooling air. The leak air is constitutionally suctioned into the drum. The fixed mixing chamber and the rotating drum cannot be sealed off completely against one another. The cooling air (approximately 20 % of the drying gas volume) has the further purpose of attaining the gas volume flow required for the transportation of items.

The furnace gas results from the combustion of primary energy carriers (e.g. heating oil, natural gas, biogas, pulverised lignite etc.) during drying combustion.

The flue gases from steam generation represent the only connection of drying to the rest of the sugar factory besides the molassed pressed pulp.

The scheme of high temperature drying in fig. 17 corresponds to the balance shown in table 3. The given figures in the balance are reduced to the most important data. For drying are only consumed 44.7 MW (=40%) of the required 111.83 MW fuel energy. In combined heat and power generation (CHP) 73.46 MW are used for net power, thereof 11.66 MW (15.8%) as electrical energy. With primary energy will be fed 67.13 MW to the steam raising unit and 11.98 MW the feeder water. In the drum drier 46.15 tons of water are evaporated per hour. This process requires a mass flow of 216 t/h (dry) drying gas. The temperature is 580°C on entering the drum. The temperature of the offgas is 100°C after the drum. The mass flow of the drying gas is consist of fifty percent of flue gases of the steam raising unit, thirty percent of flue gases of the combustion for drying the beet pulps and 20% of „leak“ and cooling air. The energy flux of the drying gas consist of 15 % of flue gas from the steam raising unit, 84 % of flue gas from the combustion for drying and 0.5% from the „leak“ and cooling air. The specific use of primary energy for water evaporation is shown as 968 kWh/t = 3,487 kJ/kg. The specific sum of the added heat energy is about 1,025 kWh/t = 3,690 kJ/kg.

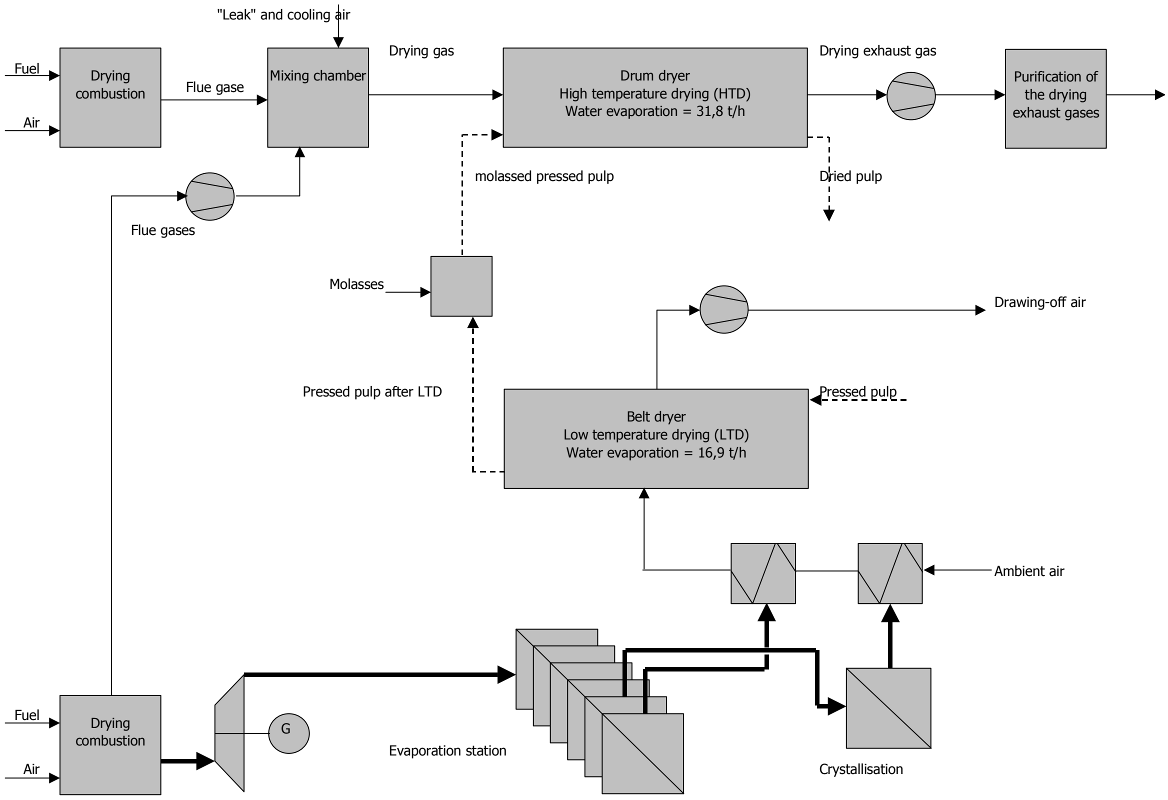


Figure 17: High temperature drying of beet pulp

3.2 Two-stage (high and low temperature) drying

Figure 18 depicts the scheme of a form of high temperature drying in combination with low temperature drying. The resulting molassed pressed pulp has a higher dry substance content, because water has already been extracted from it during low temperature drying.

After low temperature drying, the pre-dried pressed pulp is molassed. Low temperature drying, also a form of evaporation drying, precedes high temperature drying due to the lower propulsion forces. The implemented air mass and volume flow during low temperature drying is markedly higher than during high temperature drying. Due to the relation of item mass and gas volume flow, a belt dryer is utilised for low temperature drying and the gas and chip flow are brought into cross-flow in relation one another.

The drying air for the low temperature dryer can be heated by means of vapours (water steam) and condensates from the sectors of the evaporator station, crystallisation and exhaust air purification. In this way it is possible to utilise secondary energy and to lower the utilisation of primary energy for high temperature drying.

The interrelationships of sugar extraction and drying exist in this process on the basis of the flue gases, the molassed pressed pulp and the vapours for air heating.

The most important balance data for this drying installation are contained in fig. 18. With the low temperature drier will be achieved 38% of the 46 t/h water evaporation. This result requires 9.7 times the quantity of gas in comparison to the high temperature drier. The specific use of energy is 1.951 kWh/t = 7,025 kJ/kg.

The energy input by the drying gas is 34 MW (1,943 kWh/kg = 6,995 kJ/kg) with the low temperature drier and 41 MW (1,436 kWh/kg = 5,170 kJ/kg) with the high temperature drier.

The energy requirement is higher for the low temperature drier than for the high temperature drier. The use of a low temperature drier has only a positive effect when energy flows previously unused can be used to pre-warm drying air.

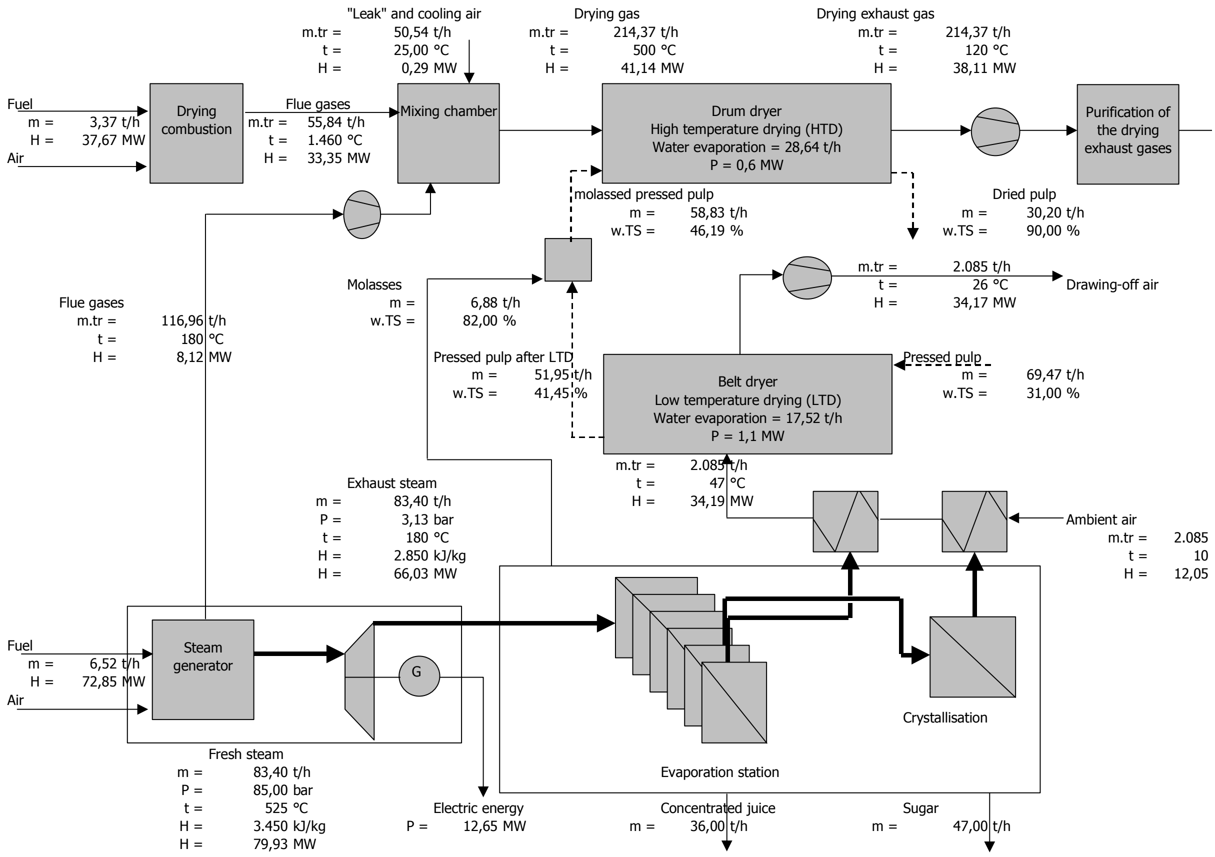


Figure 18: Schematic diagram of high temperature drying in combination with low temperature drying plant.

3.3 Evaporation drying

Figure 19 contains the most important data of the process. Of the 73,72 MW of fuel energy only 6,59 MW is needed for drying. 67,13 MW of fuel energy would in any case be required for a factory without drying (s. tab. 3). With the aid of the gas turbine preceding the waste heat boiler, in which 4 MW, and the back pressure steam turbine, in which 7,92 MW of electrical output, a more or less equalised power-heat coupling can be ensured, although a considerable portion of the steam that is output by the back pressure turbine at approximately 27 bar is not fully available for conversion into electrical energy.

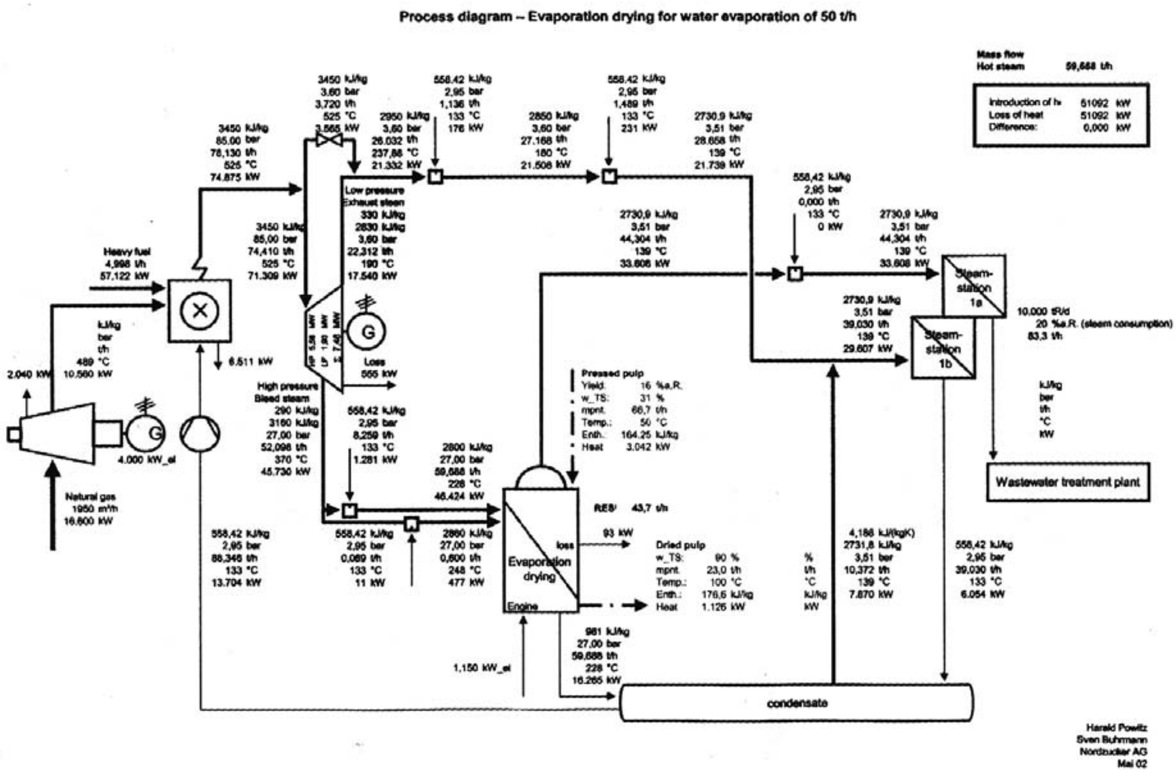


Figure 19: Schematic representation of evaporation drying (Niro DDS model)

4. Review of the given examples

In the tab. 4, the selected data for a feasibility comparison of the example plants are summarised. The basis for these are the standardisations outlined above. Possible minor differences in revenue for by-products are disregarded.

The prices of fuel and of electricity purchased and sold are assumed to be the same for all variations. A figure of 16 €/MWh corresponds to the costs for natural gas normally paid by the sugar industry in 2002. 40.9 €/MWh were charged for electricity purchased and 20.4 €/MWh for electricity was sold. From the figures for energy required and electricity sold multiplied with the prices, we get the total energy costs in €/h. By multiplying this amount with the assumed length of the season we see how much the model factories spend on energy each year (last line, tab. 3).

The running costs for the provision of energy for a factory with an evaporation dryer are $2{,}554 \cdot 10^6$ €/a, for a factory with a high temperature dryer $3{,}845 \cdot 10^6$ €/a, and for a factory combined with low and high temperature dryers $3{,}661 \cdot 10^6$ €/a.

Technical prerequisites for this difference are steam generation plants with the following exhaust steam parameters: 85 bar and 525 °C. At a number of factories, power-heat coupling with a fresh pressure of 40 to 60 bar is utilised. Own production of electrical energy in such instances is lower and is further reduced substantially during the extraction of steam at a pressure of approximately 25 bar. At a live steam pressure of 40 bar, a turbine that operates at a bleed pressure of 25 bar is no longer economical. Power-heat coupling for this flow of steam has to be relinquished.

In addition, the electrical energy balance of a factory can only be structured in an equalised way with an evaporation dryer when a gas turbine is operated. The subsequent steam generator must be able to benefit the exhaust gas flow of the gas turbine. Not utilising a gas turbine results in an acquisition of electrical energy of 3,63 MW instead of an output of 0,37 MW. The recurring costs for energy provision for this situation amount to $2{,}9 \cdot 10^6$ €/a. The savings drop to 0,95 million €/a.

Only by means of a steam and gas cycle plant with a correspondingly high live steam pressure can a sugar factory that operates an evaporation dryer record lower energy expenses. In the instance being researched, the savings in relation to high temperature drying amount to $1{,}31 \cdot 10^6$ €/a or $1{,}13 \cdot 10^6$ €/a in relation to a combination of low temperature dryers and high temperature dryers.

In the evaporator in which the exhaust vapours of evaporation drying are condensed, a condensate results that requires treatment. The mass flow corresponds to the mass of the water evaporation. When the existing plants for effluent treatment are not sufficient to process this volume, a corresponding capacity needs to be created. In the feasibility study, the costs of additional effluent treatment and other integration are not included.

		Evaporation dryers	High temperature dryers	Low and high temperature dryers	Factory without dryers
Total electric energy demand	**MW**	**11,55**	**11,20**	**12,10**	**10,40**
Total fuel energy	**MW**	**73,72**	**111,83**	**104,80**	**67,13**
Total electric energy output	**MW**	**11,48**	**11,66**	**11,66**	**11,66**
Electric energy supply	MW	0,07	0,00	0,44	0,00
Electric energy output	MW	0,00	0,46	0,00	1,26
Fuel energy price	€/MWh	16,00	16,00	16,00	16,00
Electric energy supply price	€/MWh	40,90	40,90	40,90	40,90
Electric energy output price	€/MWh	20,40	20,40	20,40	20,40
Fuel costs	€/h	1.180	1.789	1.677	1.074
Electric energy supply costs	€/h	0,00	0,00	18,00	0,00
Earnings from electric energy output	€/h	7,55	9,38	0,00	25,70
Total energy costs	€/h	**1.182**	**1.780**	**1.695**	**1.048**
Campaign length	h/a	2.160	2.160	2.160	2.160
Fuel costs	10³ €/a	2.548	3.865	3.622	2.320
Electric energy supply costs	10³ €/a	0,00	0,00	38,87	0,00
Earnings from electric energy output	10³ €/a	16,30	20,27	0,00	55,52
Total energy costs	**10³ €/a**	**2.532**	**3.845**	**3.661**	**2.264**
Price of thermal energy = EUR 16.000/MWh *Price of electrical energy = EUR 40,90/Mwh* *Campaign length = 2.160 hours/yr* *Price of electrical output = EUR 20,40/Mwh*					

Table 4: Comparison of energy costs of different ways of drying beet pulps

The comparison of energy costs for a factory without dryers indicates the following additional costs for drying during the individual processes:

- High temperature dryers: 1.581 10^3 €
- Evaporation dryers: 268 10^3 €
- Low and high temperature dryers: 1.397 10^3 €

A feasibility study of the drying procedures described above cannot only consider the energy aspects, but must also take investment costs into consideration. The capital value of the investment can be calculated, taking into account the data on the drying procedures given in tables 3 and 4. The result of the tests compare the advantages of the drying procedures examined. The aim was to find out whether additional investment expenditure for a more complex drying installation compared to high temperature drying could be compensated by lower fuel costs. Not only the fuel costs, but also operation-related expenditure for maintenance, insurance and operating personnel were taken into account. Investment expenditure was estimated.

For high temperature drying the operation-related costs amount to 388.000 € p.a. and are the lowest for all drying installations, because this is the least complex type of installation. The costs for the factory with the evaporation driers amounted to 554.000 € p.a.

The cash value of the investments at € 38,4 million for the HTD variant is the most favourable, followed by the LTD and HTD combination at € 40,6 million. ED represents the least economical option at € 40,8 million.

An overall evaluation of feasibility was not made. From the above mentioned tests, calculations show that high temperature drying was least expensive, once the service life of the installation, interest rates and energy prices were taken into consideration. Under the conditions we were looking at, the reduced annual cost of evaporation drying of about € 1.1 million compared with high temperature drying would not justify the additional investment according to the criteria of the net present value method.

Applicability

Steam heated fluidised bed drying with integrated steam system is a very attractive option for a new sugar plant or for complete reconstruction of its energy generation and heat switching facilities. However, it cannot easily be integrated into an existing conventional plant without reconstruction the steam generation and electricity production sections, for example, revising the entire heat flow set-up without the plant.

Low temperature drying can be used if the waste energy produced in the sugar manufacturing (evaporation, crystallisation) can be utilised in the drying operation.

Economics

Energy costs increase slightly more than 10% if a fluidised bed dryer is used compared to a plant without drying. In case of the high temperature drying, the energy costs increase by about 70%. Here, energy costs, however, can be decreased if high temperature drying is preceded by low temperature drying. However, overall, the investment costs are the highest for the fluidised bed drying (and gas turbine) option (€ 12 millon per evaporation dryer for 12 to 25 t/hour evaporation) and smallest for the option with a high temperature dryer.

Achieved environmental benefits

The advantage of steam dryers is their closed design, which prevents any escape of gaseous emissions (odours).

Cross-media effects

The water content of exhaust drying media is normally removed by condensation. A significant amount of condensate is produced in this process. Figures for fluidised bed drying process show that about 0,6 – 0,7 t condensate/tonne of pressed pulp are generated with an organic load of 0.20 – 0.25 kg TOC/t pressed pulp. The condensate requires treatment. If the existing effluent treatment plant capacity is not sufficient to treat the amount produced, then an additional treatment capacity will be needed.

Reference literature

1. VDI Guideline 2594 "Emission control – Pulp production in the sugar industry", (Draft 2003), Verein Deutscher Ingenieure, Berlin (2003), Beuth-Verlag .

2. BREF "Food, Drink and Milk", Draft 2003, http://eippcb.jrc.es

Plenary session
Innovative energy efficiency examples of different industrial sectors -
Energy efficiency in pulp & paper and sugar industry

REDUCTION OF ENERGY CONSUMPTION BY THE AUSTRIAN SUGAR FACTORIES IN THE PERIOD 1990 – 2002

Josef Merkl
AGRANA Zucker GmbH, Reitherstraße 21-23, A-3430 Tulln, Austria

REDUCTION OF ENERGY CONSUMPTION BY THE AUSTRIAN SUGAR FACTORIES IN THE PERIOD 1990 – 2002

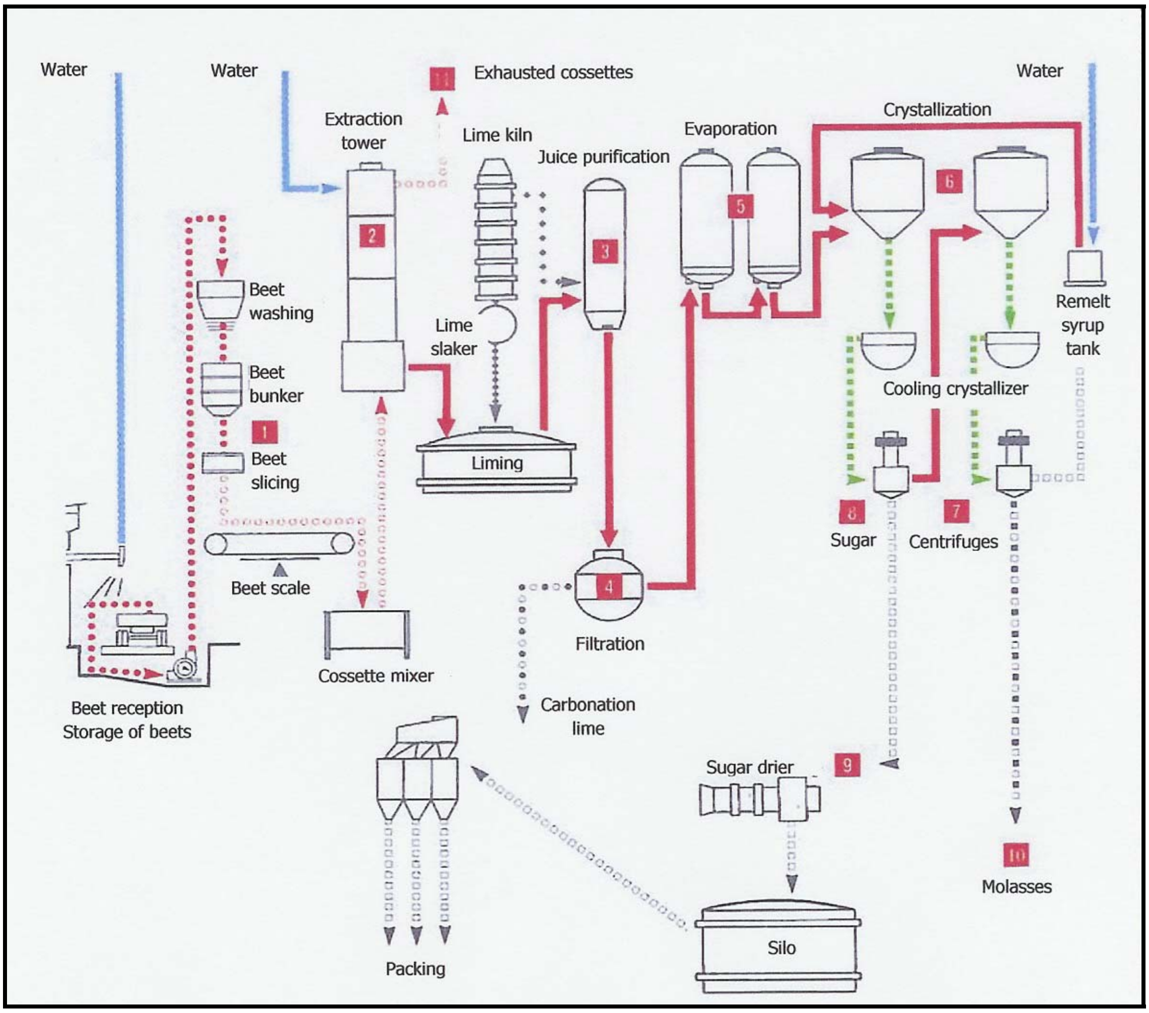
Josef Merkl, *AGRANA Zucker GmbH*

1 Introduction

The Austrian sugar industry is constantly striving towards saving energy because of global warming, the limited availability of raw materials and business efficiency.

Sugar production – the so-called "Beet Campaign" – takes up to 100 days, depending on the quantity of beet harvested. The AGRANA Zucker GmbH operates 3 factories in Austria with a daily processing volume of 12,000 tons sugar beet each.

The basic manufacturing process for sugar production is shown here in a simplified process flow chart:



The sugar beets are delivered to processing from a temporary store after being thoroughly washed. In the **pulp production [1]**, cutting machines slice the beets up into "cossette"-strips, which have a sugar content of between 16 and 20 percent. During **juice extraction [2]**, the sugar is extracted from the cossettes by conveying them upwards through a countercurrent stream of hot water (ca. 70 degrees Celsius). This produces the "raw juice". It contains around 98% of the beet sugar as well as organic and inorganic substances (so-called "non-sucrose content"). During **juice purification [3]**, a part of the non-sucrose content in the raw juice reacts with the natural materials lime and carbon dioxide – produced in our own lime kiln – and precipitates out. The precipitated, insoluble non-sucrose content and the lime are filtered out in the **filter units [4]**. The filtrate is called the "thin juice" and the filter residues are called "carbonation lime". Carbonation lime is a valuable fertilizer and is returned to the fields. The thin juice is concentrated in a multi-stage **evaporation process [5]**. "Thick juice" is the result. This thick juice is further concentrated under vacuum in the vacuum pans. **Crystallization [6]** is initiated by adding ("seeding") a finite number of crystal fragments in form of a slurry (e.g. finely ground sugar) to the juice. The crystals grow to the required grain size by further concentration. The sugar crystals are separated from the syrup by **centrifugation [7]**. The separated syrup is subjected to another two crystallization stages. The crystal-clear **sugar [8]** produced in this manner appears white due to light refraction in the crystals. White sugar has a sucrose content of at least 99.7%. The rest is simply moisture. White sugar is dried in a **sugar drier [9]**, cooled and stored in silos. The sugar is then sent on its way to the consumer in a variety of forms, packaged as required for domestic or industrial use. The syrup separated out at the last crystallization stage is called **molasses [10]**. The molasses contain the sugar that cannot be crystallized (7-10% of the beet sugar) and the soluble non-sucrose content of the beet. It is a high quality raw material for baking yeast and animal feed industries, as well as for alcohol and citric acid production. The **exhausted cossettes [11]** in the extraction tower are mechanically pressed and then mixed with molasses in drying drums to produce a material with a dry substance content of around 90% which is then pelleted (pressed) and sold as animal feed throughout the year.

Large amounts of energy are required for sugar production. The steam for the individual warming and steaming processes is generated in a boiler house where primary energy is converted in boilers to high-pressure steam which is initially used to generate electrical energy in steam turbines and then, as a lower-pressure steam, used as process steam for heating the evaporation station. A sugar factory therefore supplies itself to a great extent with electrical energy through this "combined heat and power"-system.

A sugar factory, based on the production process, can be divided into two process sections with regards to energy consumption, as shown in summary here:

- Systems for sugar production (beet reception, beet storage, beet processing, juice extraction, pulp pressing, juice purification including lime kiln, evaporation and crystallization, sugar storage and shipping, boiler system for steam production, turbines, water and waste water networks)
- Systems for production of dried pulp (pulp drying station, pellet station and storage)

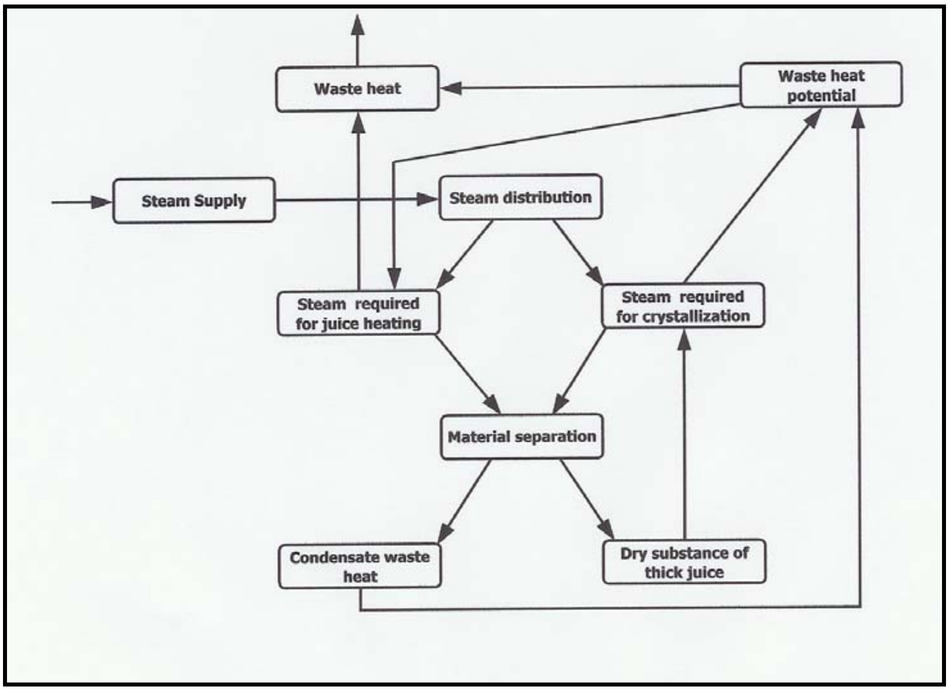
This means that the energy consumption (fuel requirements) of a sugar factory are also divided into the following main sections:

- Energy consumption for sugar production (steam and power generation)
- Energy consumption for pulp drying

To compare the processes, the energy requirement is calculated according to the processed beets volume and the products volume produced (sugar or dried pulp) and the units are expressed as MJ/t beets (MJ/t B), MJ/t sugar (MJ/t S) or MJ/t dried pulp (MJ/t DP). The energy requirements of a sugar factory are also influenced, in addition to the process engineering processes, by the raw material quality of the beets themselves. Energy requirements may fluctuate within certain limits due to the fluctuating contents (e.g. sugar content of the beets) even though the process remains unchanged.

An essential task for sugar engineers is continuous improvement of the sugar production processes. This task encompasses the development of new processes, improvement of existing processes and modification of processes to meet new outline conditions and new opportunities engendered by general technical progress.

During development, process steps were increasingly being coupled together via the energy flows. This improvement in efficiency during energy converting results in a permanent increase in energy productivity. The following diagram shows, using a segment of the sugar factory system, an example of the linkages between material separation, steam distribution, waste heat utilization and steam requirements:



The current state of energy cycles in sugar beet factories is based on evolutionary developments since the beginning of the 20th century. The steam requirements for heating juices and syrups, and for crystallization, were practically halved between 1975 and 1990. On average, heat is reused 5 to 6 times during sugar production before it is output as waste heat to the environment. The smoke gas from the boiler is mixed with the hot combustion gas for the high temperature pulp drier. The fuel energy used here is only used once.

2 Energy consumption of Austrian sugar factories

The energy costs have a great influence on the economic efficiency of a sugar factory. In 2002, the energy costs in the Austrian sugar industry made up 15.6% of the net production value. There is practically no possibility for the sugar industry to pass on energy price increases via the white sugar price to the consumer.

The specific energy consumption for production must be examined for the analysis of progress in rational energy utilization. The specific energy requirement reduction for sugar production and pulp drying achieved between 1990 and 2002 is the result of many individual measures which have significantly changed the process control and heat systems of the sugar factories.

Heat requirements during sugar production are mainly determined by the process steps extraction, juice purification and crystallization and from the multiple usage of the process heats. During the evaluation period, i.e. since 1990, all temperature drops have decreased and the specific water evaporation has been reduced by avoiding dilution. The evaporation systems have been increased from four effects to five or six effects. This requires low temperature drops, which is made possible by using downflow evaporators which can evaporate highly viscous sugar solutions with low temperature drops. Juice heating is achieved at smaller temperature differences using larger heating surfaces and this is mainly done with plate heat exchangers. Great improvements were achieved in crystallization with regards to product quality and temperature drops by the use of stirrers. The energy requirements for sugar production are characterized by the steam requirement data of the evaporator stations. The steam requirement data are given in kg/100 kg beets (% o.B.)

The energy requirements for pulp drying are determined by the energy consumption for the mechanical and thermal dewatering. The reduction of energy consumption is mainly due to the improved mechanical pressing before pulp drying and the optimization of the existing drying drum equipment. A further reduction of energy consumption in these systems can only be achieved by increasing mechanical pressing and optimizing the capacity utilization of the individual systems. Process engineering improvements to the directly heated drying drum equipment are practically exhausted.

The reduction in CO_2-emissions is partly due to the reduction in fuel consumption and the CO_2-relevant consumables lime and coke, and partly due to the exclusive use of natural gas as the fuel for the boiler house and pulp drying since 1996.

3 Measures to reduce energy consumption between 1990 - 2002

The following chapter looks at the measures implemented by AGRANA to reduce energy consumption and CO_2-emissions during the 1990-2002 period. The practical effects of the measures implemented by AGRANA in the individual factories were checked and evaluated with theoretical calculations.

Hohenau factory:

In 1990, the steam boiler and pulp drying were converted to natural gas operation. This provided the possibility of using a fuel with lower CO_2-emissions in addition to heavy fuel oil.

A new extraction tower was erected in 1991. This reduced the energy requirements for sugar production from 5,923 to 5,184 MJ/t S (-12%). This is calculated from the fact that the new extraction tower reduced the raw juice draught from 117.5% to 104.6% and therefore the factory steam requirements by a theoretical 2.6% o.B., which in turn reduced the overall energy requirements for sugar production by ca. 10% - which is equivalent to the practically achieved reduction. The installation of a new pulp press increased the dry substance (DS) content in the pressed pulp from 26.5 % to 29%. This leads theoretically to a fuel savings of 0.17% o.B. or a reduction in energy requirements for dried pulp of ca. 12%. In practice the energy requirements were reduced from 6,480 to 5,599 MJ/t DP. This is equivalent to a reduction of 14%. The practical results were substantiated by the theory.

In 1997, the evaporator station was renewed to a 6-stage operation, including the pre-warming station. This optimized the multiple juice vapor utilization. The energy requirements for sugar production were significantly reduced and were on average 1,000 MJ/t S less than in the previous years (4,267 MJ/t S).

In 1998, the waste heat was reused to heat the raw juice (with a sediment from the wet dust removal in pulp drying; the optimization of waste heat utilization is an important step in energy consumption reduction) and the vacuum pans in the sugar end were equipped with stirrers and larger heating surfaces. This meant that they could be heated with lower temperature juice vapours, thus reducing the factory steam requirements and improving the sugar quality, leading to water and therefore energy savings due to less wash water requirements. The sugar production energy requirements could be reduced by another 5% compared to the previous year.

In 1999 and 2000, the success of waste heat utilization and modernization of the vacuum pans was continued. The sugar production energy consumption continued to be successively reduced. The installation of a new pulp press increased the dry substance content of the pressed pulp from 30.4% to 31.6%, which corresponds theoretically to a fuel savings of 0.06% o.B. or an energy reduction around 5%. In addition, broken beet-piece processing was renewed and a beet-grass press was installed. This increased the initial dry substance content in the pulp drying and therefore led to a significant reduction in energy requirements. In practice, the energy requirements for pulp drying was reduced by 13% this year compared to the previous year and will continue to be reduced in the following years.

Modernization in the area of juice purification and the sugar end was implemented during 2001-2002. In juice extraction, CO_2-distribution in the carbonators was renewed, which enabled better CO_2-utilization, lower lime requirements and therefore lower CO_2-emissions. In addition, these measures reduced heat losses in the carbonation vapours, reducing steam and therefore energy requirements. In the sugar end, the conversion of raw sugar crystallization to continuous production and modernization of the vacuum pans with stirrers made it possible to heat the rear stages of the evaporator station with lower-pressure vapours, which led to a further reduction in the overall sugar production energy requirements.

Hohenau factory results:

Between 1990 and 2002, the specific energy consumption for sugar production in the Hohenau factory dropped from 5,923 to 3,930 MJ/t S. This corresponds to a reduction of

1,993 MJ/t S or 33.6%. The main savings made in sugar production was partly due to the new investments in extraction (1991), but mainly due to the evaporator station in 1997, which enabled successive improvements to the thermal balance of the factory. The reduction of lime utilization led to lower mass flows and also reduced energy requirements.

Energy consumption in pulp drying during the same period drop from 6,480 to 5,342 MJ/t DP - mainly due to the increase in dry substance content in the pressed pulp caused by the new pulp presses. This corresponds to a reduction of 1,138 MJ/t DP or 17.5 %. In addition, product output was increased while the overall energy requirements sank.

The total investment sum for modernization of the energy system during this period was approx. 22 million EUR.

Leopoldsdorf factory:

In 1990, the boiler house and pulp drying were converted to natural gas operation.

The beet washing house was replaced in 1991 in the sugar production area. Clean beets are a basic requirement for energy-optimal processes (less contamination of heat exchangers, etc.). This measure therefore leads to a reduction of energy consumption but cannot be quantitatively evaluated.

In 1993, modernization and optimization of the evaporator station reduced the sugar production energy requirements, in comparison to the previous year, by 14% from 5,504 to 4,733 MJ/t S. The refurbishment of the beet slicing station improved extraction processes and therefore juice quality, enabling the entire sugar processing to be operated more consistently and therefore more energy optimized.

In 1994, additional decanters (thickeners) were added in the juice purification. This led to less thin juice colour, which in turn led to less wash water volumes and reduced run-off dilution throughout the process in the sugar end, enabling a reduction in energy requirements. The energy consumption was reduced by another 4% compared to the previous year.

The lengthening of an extraction tower to cope with the successive increase in beet processing and sugar recovery by means of a new after-product vertical mixer in 1996 led to a further reduction in sugar production energy consumption of 8% compared to the previous year.

New pulp presses were installed in 1997. This reduced energy consumption, compared to the previous year, by 19%.

In 2000, the replacement of heating chambers and the installation of a white sugar centrifuge optimized crystallization processes leading to less wash water and energy requirements.

Leopoldsdorf factory results:

Between 1990 and 2002, the specific energy requirements for sugar production in the Leopoldsdorf factory dropped from 5,471 to 4,225 MJ/t S. This corresponds to a reduction of 1,246 MJ/t S or 22.8 %. The main savings in sugar production were due to the new investments in the evaporator station area in 1992/93 which enabled consistent improvement of the thermal balance of the factory. The reduction of lime utilization led to lower mass flows and also reduced energy requirements as in Hohenau.

The pulp drying energy consumption was reduced, over the same period, from 5,873 to 5,147 MJ/t DP. This corresponds to a reduction of 726 MJ/t DP or 12.4 %. In the pulp drying area, the increase in dry substance content of the pressed pulp due to new pulp presses was the main reason for the energy consumption reduction.

Product output in Leopoldsdorf was also increased while the overall energy requirements sank.

The total investment sum for modernization of the energy system during this period was ca. 35 million EUR.

Tulln factory:

Some of the measures implemented in Hohenau and Leopoldsdorf after 1990 were implemented at the Tulln factory before 1990. These included the conversion of the boiler system and the pulp drying to natural gas operation and the modernization of the evaporator station. Tulln therefore already had a significantly lower energy level for sugar production in 1990 compared to Hohenau and Leopoldsdorf (5,176 MJ/t S)

In 1990, the after-product station in the sugar end was set to continuous operation. The related steam savings – by conversion to heating vapours with lower temperatures – together with increasing beet processing and better utilization of factory capacity resulted in a sugar production energy consumption reduction of 10%. A new pulp press reduced energy consumption for pulp drying by 12% (1990-1992).

In 1996, the sugar recovery was significantly increased by the installation of a new after-product vertical mixer, which reduced the sugar production energy requirements.

Optimization in the sugar end and heat exchanger areas, together with improved utilization of the systems because of increased beet processing between 1997 and 1998, led to further reduction in energy consumption for sugar production.

Energy consumption for sugar production was reduced by another 10% in 1999. This was mainly due to the increase in beet processing by ca. 850 t/d and the resulting improved system capacity utilization.

The optimization of the slicing machines and the pulp press installed in 1999 led, following the optimization phase, to an increase in dry substance content of the pressed pulp from 30.2% to 33.6% in 2002, resulting in a energy decrease of 15%.

Tulln factory results:

Between 1990 and 2001, the specific energy requirements for sugar production in the Tulln factory dropped from 5,176 to 4,699 MJ/t S. This corresponds to a reduction of 477 MJ/t S or 9.2 %. The main savings in sugar production were due to the new investments in the evaporator station area in 1990 (1988) which enabled successive improvement of the thermal balance of the factory. The reduction of lime utilization led to lower mass flows and also reduced energy requirements.

The pulp drying energy consumption was reduced between 1990-2002 from 5,883 to 4,461 MJ/t DP. This corresponds to a reduction of 1,422 MJ/t DP or 24.2 %. In the pulp drying area, the increase in dry substance content of the pressed pulp due to new pulp presses was the main reason for the energy reduction. Overall, the increase in beet processing at the Tulln factory – greater than in the other factories – had a positive effect on the energy-optimal utilization of the existing systems.

The total investment sum for modernization of the energy system during this period was ca. 21 million EUR.

4 Evaluation of energy requirements based on benchmarking values

The energy requirements of sugar factories is dependent on various stations in the production process, whose comparison with benchmarking values can provide the possibility of evaluating the energy consumption in these factories. Benchmarking values in this respect are energy data that basically reflect the average values of Western European sugar factories. Benchmarking values cannot always be understood as "best practice" values, they simply serve to evaluate the rank of a system within a list of similar systems.

The benchmarking values for energy requirements of sugar production and pulp drying were defined as follows:

The benchmarking values for sugar production energy consumption were derived from a global benchmarking survey implemented by IPRO Industrieprojekte GmbH (D-Braunschweig) in 2000 for the Dutch sugar factories for the comparison year 1997 [1]. As a criterion for the sugar production benchmarking value, the limit value of the best 10% of sugar factories was extrapolated for 2001 (assumption: reduction of energy consumption by 2% per year and reduction of overall number of sugar factories by 30 per year). The limit value of the best 10% (position 75) based on 1997 energy values is 5,600 MJ/t sugar with a total of 750 (previously 870) sugar factories around the world. This meant that a benchmarking value for sugar production was calculated at 5,170 MJ/t sugar for 2001. The average value of the best 10 Western European factories was selected in this survey as the "best practice"-value for the sugar production energy consumption. This value is 4,230 MJ/t sugar. "Best practice"-values must always be locally defined as the steam - and therefore energy - requirements for combined heat and power systems varies, dependent on the electric energy consumers (various production systems on site).

The benchmarking value for pulp drying energy consumption was set according to the energy consumption calculation for a 30% dry substance content of pressed pulp and is 5,300 MJ/t DP. The "best practice" value for pulp drying energy consumption was set according to the energy consumption calculation for a 30-33 % dry substance content of pressed pulp and is 4,800 to 5,300 MJ/t DP. The comparison values for the dry substance content is therefore set significantly higher than the values given in the "Draft Reference Document on Best Available Techniques in the Food, Drink and Milk Industry" - published in May 2003 - where the pressed pulp has 25-30 % dry substance content [2].

With regards to the energy consumption for sugar production and pulp drying, the Austrian sugar industry is already positioned on the lower range of the logarithmic optimization curve so that further energy saving measures will no longer enable "large" reductions within combined heat and power systems.

The following sections summarize and explain the process and energy data – divided by process stations that characterize, in terms of energy, the sugar production process:

Energy requirements for sugar production

Extraction:

All AGRANA factories are within the benchmarking values for Western European sugar factories. The raw juice draught reflects the capacity of the extraction systems. Modern extraction systems achieve a raw juice draught of 100-105% with low sugar losses. Draught values between 105-110% are a good average.

Juice purification:

In the sector of juice purification, the temperature to which the juice being processed is heated with waste heat, is an indicator for the energy consumption evaluation. This temperature should lie between 75-80 °C, which is the case in all AGRANA factories. In addition, the temperature of the utilized condensate should lie between 60 and 65 °C so that good waste heat utilization is present. The condensate temperature is however just a reference point for good energy budgets, deviations can also be due to process differences (e.g. utilization of crystallization vapours for raw juice warming). Consistent reduction of lime and therefore coke consumption significantly reduces mass flow, energy consumption and therefore CO_2-emissions.

Evaporator station:

The concentration of the thin juice in the evaporator station to a dry substance content of 75% is an important requirement for the reduction of steam consumption in the sugar end and in the entire factory. This value was reached, with the exception of Leopoldsdorf, in the other two factories. Further modernization steps in the evaporator station are required in Leopoldsdorf, with which the energy consumption for sugar production can be reduced by ca. 8-10% with the follow-up measures.

Boiler house:

The overall energy consumption for sugar production in the 3 AGRANA factories in 2002 was below the benchmarking value of 5,170 MJ/t S with 4,200-4,300 MJ/t S.

Energy consumption for pulp drying

Pulp presses:

The mechanical pressing of the exhausted wet pulps is an important factor for energy consumption in pulp drying. All factories achieved the benchmarking value of 30% in the pressed pulp. The "best practice" method indicates a dry substance content in pressed pulp of 30-33% which is achievable with modern pulp presses. Hohenau is within this range with 31.6%. Dry substance content values in the pressed pulp of over 33% were reached in 2002 in the Tulln factory.

Pulp drying:

All three AGRANA factories reflect the benchmarking value of 5,200 MJ/t DP with their pulp drying energy consumption, and this corresponds to a dry substance content of 30% in the pressed pulp. Further reduction of energy consumption for the high temperature drum drying is only possible by increasing the pressed pulp dry substance content by means of optimal and capacitive utilization of the systems. Alternative drying techniques were discussed in another report.

Rank list for the primary energy requirements of sugar production and pulp drying within the investigated Western European sugar factories:

Im Bereich der Zuckerproduktion belegen die Werke Hohenau Platz 13, Leopoldsdorf Platz 15 und Tulln Platz 8 in der Rangliste der 46 untersuchten, besten westeuropäischen Fabriken.

In the sector of pulp drying, Hohenau was at place 15, Leopoldsdorf at 18 and Tulln at 17 in the rank list of the 29 best Western European factories evaluated.

5 Evaluation of the future savings potentials for technically feasible measures to reduce energy consumption and their efficiency

No further optimization potential was determined by IPRO Industrieprojekt GmbH in the sugar production of the Hohenau factory. Reduction of energy consumption in the pulp drying could be increased by raising the dry substance content of the pressed pulp by 33% through further modernization of the pulp press station. An initial estimation is that by increasing the DS content from 31.3% (average of past 3 years) to 33%, the fuel consumption for pulp drying could be lowered by ca. 0.1 % o.B. This corresponds to a reduction of energy consumption in pulp drying of 8%. The investment costs for the modernization of the pulp press station with 4 large pulp presses would be ca. 5.6 million EUR. With the assumed fuel price of 14.7 Cent/Nm^3 natural gas this would produce a fuel savings of 90,000 EUR/a. The investments costs would only be recouped after 62 years.

To reduce the energy requirements at Leopoldsdorf, the overall heating area within the evaporator station must be increased by ca. 20,000 m^2. The energy savings calculated directly from the increase of thick juice dry substance content from 70 to 75% are 1.2 % o.B. This corresponds to a reduction of energy consumption in sugar production of 5.5 %. Further energy saving measures would be possible if the evaporator station is expanded (e.g. increase in condensate utilization, switching of vapours to rear evaporator stages) and these should result in an overall reduction in energy consumption for sugar production of 8-10%. The investment costs for the evaporator station are ca. 10 million EUR. Further investments in the sugar end and heat exchangers would be necessary, however those costs are not calculated here. Fuel savings would be ca. 22,000 EUR/a and the recouping period would therefore be more than 45 years. In order to reduce energy requirements for pulp drying, the pulp press station would require modernization with three new pulp presses to increase the current dry substance content of the pressed pulp from ca. 30.5% to 33%. The energy requirements for pulp drying could be reduced in this manner by 0.13% o.B. or 9%. The investment costs for this would be ca. 4.2 million EUR. The fuels savings of ca. 110,000 EUR/a would only be recouped in 38 years.

At the Tulln factory, the steam requirements could be reduced by ca. 1.2% o.B. by reducing draught with an enlarged extraction system leading to an energy reduction of 5.5%. The investment costs for expanding extraction with a second extraction tower and corresponding pulp mixer would be ca. 3.5 million EUR. The fuels savings of ca. 150,000 EUR/a would only be recouped in 23 years. The dry substance content of the pressed pulp in the Tulln factory in 2002 was 33.6%. This value corresponds to the upper limit value of the "best practice" method. Investments to reduce energy requirements in this station are hardly feasible.

Technological options, which are currently being used in individual European sugar factories due to special framework conditions (e.g. vapour compression in Switzerland, due to lower electricity prices), are available to reduce energy requirements for sugar production and pulp drying, however their high investment and operating costs are economically unprofitable for Austrian factories.

The steam requirements at the Hohenau, Leopoldsdorf and Tulln factories is 20-25% o.B. and are therefore already in the lower energy optimized range. In measures to further reduce steam requirements, the internal energy supply situation must be checked as each factory has a minimum steam requirement, depending on the efficiency of the power station (boiler house and turbines) and the level of electricity requirements, which can still be met by the internal energy supply. Further reductions in steam requirements would indicate an expensive restructuring of the power station or necessitate the purchase of electricity. Both alternatives are economically not feasible.

The reduction of energy requirements in pulp drying by increasing the dry substance content in the press pulp has already been discussed (i.e. by improvement of mechanical dewatering). There are no further options for further reduction of energy consumption in pulp drying with the installed systems, if the possibility of completely avoiding pulp drying is ignored. However, removing the drying operation is only possible if the resulting pressed pulp can be completely transferred to the campaign as animal feed. The sales market must be available for this purpose.

There are alternative drying technique that could contribute to reducing the energy requirements of the thermal drying process. However, certain requirements always have to be met by corresponding framework conditions (this area will be covered by a separate report). For the AGRANA factories, the installation of pressurized steam dryers for 100% drying of pressed pulp would lead to an overall current deficit of ca. 45 MW for all three factories. With an emission factor of 0.637 t CO_2/MWh (thermal EVU mix in Austria) this is equivalent to ca. 53,000 t CO_2. In comparison to the CO_2 current emissions of the pulp drying, ca. 48,800 t, this would mean an increase in CO_2 emissions by 4,200 t/a or 2.5%. Previous installations of steam dryers were always linked to necessary capacity increases and the resulting environmental conditions. In addition, these systems were state supported in the new constructions in Germany. An economic reason for installing a steam drying system in an existing sugar factory can only be investigated individually for each single case.

In addition to the measures for reducing the energy requirements in sugar production, various publications have recently been discussing the combustion of biomass (e.g. wet pulps) in steam generators. The combustion of biomass would replace the equivalent fossil fuels – however, in the case of sugar factories, this would be burning high quality animal feed. These discussions are just beginning, but would signify a great change in the technical equipment of the power plant. In addition, the pulp would in any case still have to be prepared for combustion which means that a drying system for the pulp would still be required. In our opinion there are options here for the future energy concept of a sugar factory, if after suitable development the necessary technical equipment can provide the necessary steam output for the operation of a sugar factory.

However, the primary energy requirements for sugar production can for the time being only be influenced within the framework of the measures previously described.

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Parallel session
Innovative energy efficiency examples of different industrial sectors –
Energy efficiency in the cement, metal and petrochemical industry

CO - PROCESSING OF WASTE AND ENERGY EFFICENCY BY CEMENT PLANTS

Richard Bolwerk
Council Government Münster
Domplatz 1-4, D 48128 Münster,
E-mail: richard.bolwerk@bezreg-muenster.nrw.de

CO - PROCESSING OF WASTE AND ENERGY EFFICENCY BY CEMENT PLANTS

Richard Bolwerk; *Council Government Münster*

ABSTRACT

The cement industry is net-shaped connected to the environment. The production process requires energy and that leads to emissions. Brown coal and hard coal are the predominant sources of energy in Germany. In the past, the specific need for combustibles approached the minimum of process engineering constantly. Another need for the protection of our natural resources, is the reduction of $CO_{2.}$ The reduction of the production costs could only be made possible with the use of particular energetic waste materials.

At present, there are many cement factories in Germany which use, waste materials in the production of cement. Past experiences have shown that the cement industry can play an important role in the utilization of secondary fuels and the cement industry also makes a positive contribution to the environmentally compatible utilization of these materials.

The evaluation criteria for environmental compatibility are laid down in, among other places, the German Recycling and Waste Act. This act states that environmental compatibility of an utilisation process should be assessed mainly on the basis of the expected emissions, the energy utilisation, the residues produced and the effect on the product. Key factors include favourable conditions inside rotary tube kilns, optimized process and safety technology and improved exhaust gas cleaning systems and a comprehensive control of the input substances.

The requirements differ for each plant and these must be examined and defined as part of the licensing procedure in accordance with the Federal Immission Protection Act

The key environmental issues associated with cement production in the licencing procedere are air pollution and the use of energy. The clinker burning process is the main source of emissions and it is also the principal user of energy . There are some energy saving and energy recovery techniques for the main process in the cement industry, principally for the clinker burning process. These techniques also have to be considered in the determination of collateral regulations in the permission.

1 Introduction

The cement industry is net-shaped connected to the environment. The production process requires energy and this causes to emissions. Information on energy consumption including secondary fuels in the cement industry is relatively well known. Fossil fuels (e.g. coal, oil or natural gas) are the predominant fuels used in the cement industries. However, low-grade fuels such as petrol coke and waste derived fuels (traditionally waste oils, spent solvent, waste tyres) have been increasingly utilised in the recent years. More recently, the cement industry have also co-incinerated animal meals and animal fats.

The key environmental issues associated with cement production in the licensing procedure are air pollution and the efficient use of energy. The clinker burning process is the main source of emissions and it is also the principal user of energy . The requirements differ for each plant and these must be examined and defined as a part of the licensing procedure in accordance with the Federal Immission Protection Act. This act states that environmental compatibility of an utilisation process should be assessed mainly on the basis of the expected emissions, the energy utilisation, and the effect on the environment. The emission limits are laid down in accordance with the regulations described in TA Luft 2002 (German Clean Air Standards). If waste fuels are used in the clinker burning process as well as normal fuels, then regulation of the 17th BImSchV (Ordinance of the Federal Environmental Impact Act) also supply.

2 Incineration of waste Fuels

Hazardous waste incineration is an engineered process that employs thermal oxidation at high temperature (normally 900 °C or higher) to destroy the organic fraction of waste. Minimum temperatures required for incineration range from 875 °C for incineration of municipal garbage to 1.400 °C for incineration of more stable organic compounds such as PCB, dioxin, and residues from polyvinyl halogenide production. Residence time at the high temperature must be at least 2 seconds. Producing cement clinker in cement kilns also involves high temperature burning. Liquid waste can be introduced into cement kilns using conventional oil burners; solid waste in the form of granulated material or powder can be fired like coal dust. In comparison with other types of hazardous waste incinerators, cement kilns possess several characteristics, which make them an efficient technology for destroying highly toxic and stable organic wastes.

Combustion gas temperatures and residence times in cement kilns exceed those of commercial hazardous waste incinerators. These high combustion temperatures and long residence times, along with the strong turbulence encountered in cement kilns, assure the complete destruction of even the most stable organic compounds. Burning of cement clinker requires a material temperature of 1.400 – 1.500 °C; consequently the flame temperature must be even higher in order to obtain heat transmission from flame to material. In the case of short kilns like preheated kilns and precalciner kilns the gas temperature in the burning zone is about 2.000 °C, at mid-kiln it is about 1.700 °C, and at the kiln exit it is about 1.100 °C. The gas retention time is about 5 seconds.

The large size of kilns and the quantity of heated material present results in high thermal stability. In other words, temperatures within kilns change very slowly. Thus, even if a cement kiln is forced into an emergency shut-down resulting from a loss of primary fuel or a severe malfunction, all hazardous waste in the kiln will be completely destroyed, provided automatic cut-offs prevent further injection of wastes. Cement kilns operate under alkaline conditions. Therefore, virtually all chlorine entering a kiln is neutralised of form sodium chloride, potassium chloride, and calcium chloride, all relatively non-toxic substances. Consequently, emissions of hydrogen chloride, a strongly acidic compound, are significantly lower than emissions from commercial hazardous waste incinerators.

3 Energy Aspects by Burning CEMENT clinker

The production of Portland cement clinker is energy-intensive. Theoretically an average of 1.75 MJ of thermal energy is needed to burn 1kg Portland cement clinker. The actual requirement for thermal energy in modern plants is approximately 2.9 to 3.2 MJ/kg (BREFF 2001, CEMBUREAU 1997) depending form the process till 4 MJ/kg.

The production of cement involves four steps:

- Preparation of a material mixture;
- Thermal formation of clinker in the cement kiln;
- Clinker cooling;
- Grinding and mixing with additives to the cement quality required.

Most installations, use the dry process, which -for dry raw materials- is the most economical in terms of energy consumption. In Germany the cement clinker is burnt exclusively by dry process. As is shown by the plant layout in Fig. 1, the main components of a plant of this type are the preheater, calciner, rotary kiln and clinker cooler.

The conversion of the raw materials into clinker involves various processes at the following temperature ranges:

below 550°C:	preheating, drying and dehydratation;
550 to 900°C:	decarbonisation of $CaCO_3$ into CaO and CO_2; Decarbonisation is an endothermic reaction. A flue gas temperature exceeding 1000°C is required.
900 to 1300°C:	first recrystallisation or calcination reactions;
1300 to 1450°C:	sintering and clinkerisation. Sintering is an endothermic reaction. A flame temperature of 1800°C is required.

In a typical dry process, preheating and decarbonisation take place in a series of cyclones. The dry material enters at the top of the upper cyclone and moves downwards through the cascade into the furnace. The hot flue gases from the kiln flow counter-currently. The cyclones provide a good heat and mass transfer, thereby enhancing the energy efficiency and flue gas cleaning.

Fuel energy is use in cement production mostly to burn the cement clinker. Electrical energy is used principally to drive the extensive grinding equipment and to operate the kiln systems.

There are some energy saving and energy recovery techniques for the main process in the cement industry, principally for the clinker burning process.

The heat recovery takes place by preheating the combustion air in the cooler while at same time cooling the clinker, and by using exhaust the gas energy after the rotary kiln for calcining and preheating the raw meal in the calciner and preheater.

In the burning process in the rotary kiln sufficiently high material temperatures of ~ 1450 °C have to reached for conversion of the clinker phases. In practise, fuels with an average net calorific value of at least h u,m 20 – 22 MJ/kg are normally used in a main firing system. Preheating the air to 950 °C or more is therefore a very effective measure for recovering heat and reducing energy expenditure.

In the calciner the temperature of the kiln exhaust gas falls from about 1200 °C to the calcinig temperature of about 850 °C (equilibrium temperature). To maintain to the endothermic calcination reaction at this comperativly low temperature level, compared with the burning process, it is also possible to use here fuels of lower calorific value.

In a substitution of normal fuels by replacement fuels (waste materials), the first question which usually occurs relates to effect of the replacement fuels on the process conditions of the particular process. Particular attention has to be paid to the effects of using replacement fuels on process temperatures, exhaust gas masses, harmful substances and their levels, and specific energy expenditure, or efficiency for energy. Only then is it possible to discuss the possibilities of optimizing the process regime, e.g. recovery or by interconnected operation, for the conditions which have been altered by the substitution. The evaluation of a fuel is therefore depend not only on the nature of the fuel itself but to a considerable extent also on the mode of operation of the plant and on the heat recovery.

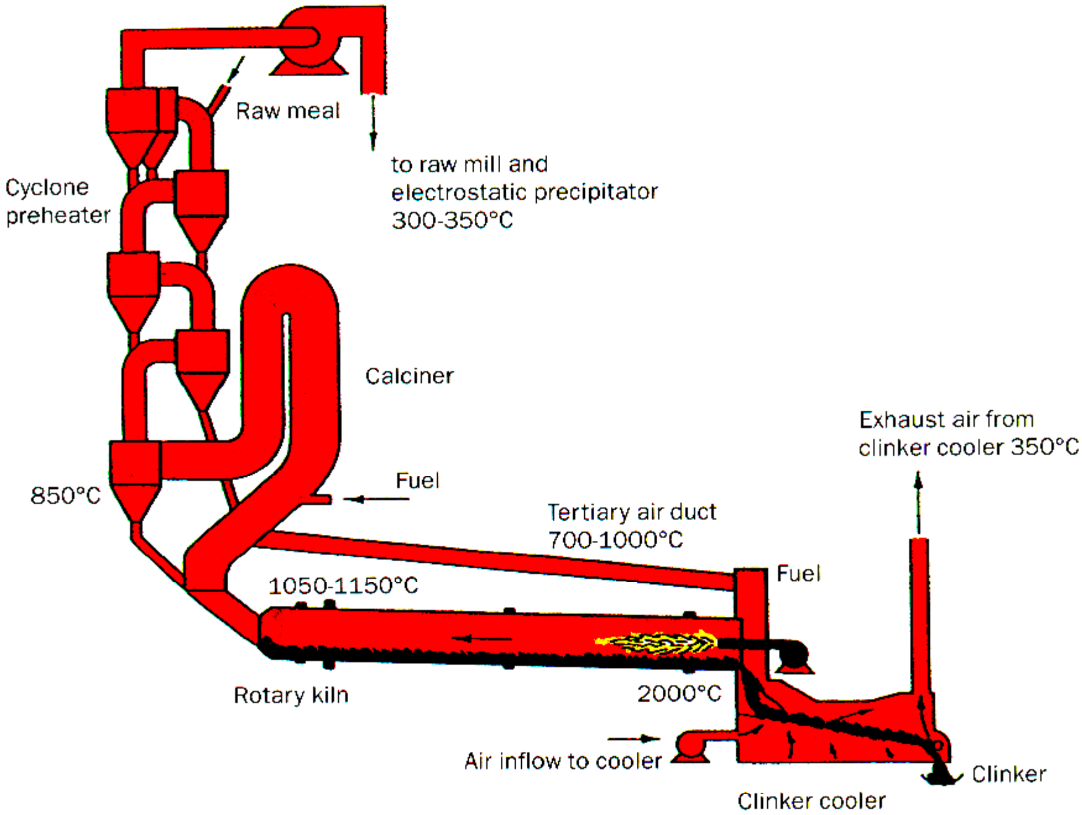

Fig. 1: Plant layout

The fuel can be fed to the kiln at the following points:

1. Via the main burner;
2. At the transition chamber at the rotary kiln inlet via a feed chute (large pieces of fuel);
3. At the riser pipe via secondary fuel burners;
4. At the precalciner via precalciner burners;
5. At the precalciner via a feed chute (large pieces of fuel);

A preheater / calciner kiln system uses cyclones to preheat the raw materials, and an additional vessel, a calciner, which up to 60 % of the total fuel to be burned in a secondary , lower temperature combustion zone. The addition of energy in the calciner increases the degree of calcination from 30 to 40 % typical in a preheater kiln to 85 to 97 %. Calcination begins at a temperature of about 815°C, and it is substancially completed at about 955°C.

Flue gases

The cement kiln is provided with 1, 2 or 3 stacks, depending on the process configuration. The main stack is always present.

The main releases from the production of cement are releases to air from the kiln system. These derive from the physical and chemical reactions involving the raw materials and the combustion of fuels. The main constituents of the exit gases from a cement kiln are nitrogen from the combustion air; CO2 from calcination of CaCO3 and combustion of fuel; water vapour from the combustion process and from the raw materials; and excess oxygen.
In all kiln systems the solid material moves counter currently to the hot combustion gases. This counter current flow affects the release of pollutants, since it acts as a built-in circulating fluidised bed. Many components that result from the combustion of the fuel or from the transformation of the raw material into clinker remain in the gas phase only until they are absorbed by, or condensed on, the raw material flowing counter currently.

The adsorptive capacity of the material varies with its physical and chemical state. This in turn depends on its position within the kiln system. For instance material leaving the calcination stage of a kiln process has a high calcium oxide content and therefore has a high absorptive capacity for acid species, such as HCl, HF and SO2.

Part of the installations is equipped with a bypass and a bypass stack. A bypass is necessary when the chlorine content in the feed (raw material and fuel) is high. The presence of chlorine is a critical factor in the thermal process. Chlorine may react with calcium, giving CaCl2 that ends up in the clinker. However, most of it binds to sodium or potassium which leads to the formation of NaCl and KCl respectively. These latter salts sublimate in the calcination zone and recrystallise in the decarbonisation zone, which results in an internal chloride cycle. As the chloride concentration rises, salt crusts may precipitate in the installation. This may lead to blockages, for example on the cyclone pipes, resulting in a kiln shutdown.

The bypass is installed in the zone where the salt accumulation occurs. Part of the flue gas is removed here. Before emission the gas is dedusted by an electro precipitator or bag filter.

A third stack emits the air used for rapid cooling of the clinker. The gas is dedusted before emission into the atmosphere. This heated air may also be used as combustion air, which gives a more energy-efficient process.

In general the following energy information in the application is important

- total energy balance
- assessment of energy efficiency
- energy consumption
- energy saving plan
- description on energy use

4 Required Waste information in the application

The selection of rich calorific valuable residual materials and the processing of household- and commercial - refuse to rich calorific valuable substitute fuels naturally depend upon with permit has given to each individual Cement plant.

The following questions concerning the waste fuel are important:

- which residuals are used and out of which process do the waste materials come from?
- which pollutants do the waste contain ?
- the data of the used waste (calorific value, water content, heavy metals, chlorine content, PCB, etc.).
- is the statements reliability durably guaranteed ?
- is a constant quality within a certain spectrum possible ?
- what is the expected emissions (PCB, Dioxin/Furan, heavy metals) ?
- how is the enrichment of harmful substances in clinker or cement ?

A cement plant has to enclose the following documents when using waste fuels:

- a suitability proof of the processing plant, that it is recognized as a specialized waste disposal plant for the processing of residual materials of production
- proof, that the processing plant is suitable for this kind of processing and
- Documentation / Declaration of every single inorganic and organic substance of the wastes and the finished mixture of secondary waste fuels.

The following trace elements which are contained in the used materials for cement kiln are limited to median value and maximum value in the Table 2. The level for calorific- value in waste fuel from manufacturing processes is 20 ±2 MJ/kg, the calorific value content for the high calorific part of municipal waste is fixed at 16 MJ/kg.

	Median Value [ppm]	Maximum Value [ppm]
Cadmium	4	9
Thallium	1	2
Mercury	0,6	1,2
Antimony	25	60
Arsenic	5	13
Cobalt	6	12
Nickel	25 (50-80)*	50 (100-160)*
Selenium	3	5
Tellurium	3	5
Lead	70 (100-190)*	200 (300-400)*
Chromium	40 (60-125)*	120 (120-250)*
Copper	100 (120-350*	300 (300-500)*
Vanadium	10	25
Manganese	50 (100-250)*	100 (300-500)*
Tin	10	40
Beryllium	0,5	2

* Exeption limits for Ni, Pb, Cr, Mn, Cu by high calorific part of municipal waste

Table 2: Limits for heavy metals

Key parameter is the quality of the substituted fossil fuel. A low difference in burden of pollutants between conventional fuel and waste fuel strengthens the advantage of co-incineration. To compare scenario between “with and without waste fuel” it is advised to define an average fossil fuel content of heavy metals and use it for benchmarking.
It can be used for direct comparison of different types of waste fuel qualities or even serve as basis for the development of a material specific standard. The standard could be defined as an average content of heavy metals and maximum content in the high calorific waste fuel.

5 Monitoring Combustion

The main requirements for uniform kiln operation and constant operating conditions when using waste materials and waste oil. From this it follows that::

- the burning process has to be monitored continuously using modern process control technology,
- Waste materials require constantly fixed inspections on arrival and comprehensive preliminary homogenisation.
- Liquid media are sampled continuously through trickle tubes for quality control,
- the main parameters for analysis of the waste materials (calorific value, chemical composition, etc.) must be put into the process control system on a continuous basis,
- regulations of primary energy have to follow in reliance on secondary fuel data,
- the feed lance must be designed so that the waste fuel is injected centrally and is ignited at the flame front of the main fuel,
- The control units must allow the waste fuel to be supplied independently of the main fuel,
- waste fuels may only be supplied during normal continuous operation within the rated output range.

The description of a safety chain and safety regulations is necessary for supervising a firm combustion to recognize defects immediately and to avoid uncontrolled combustions of secondary fuels with suitable contact systems. The parameters of the ″ safety chain″, listed below, should be linked to one another by a computer-controlled logic system so that their effect on kiln operations and on emissions can be ascertained and the operation could be shut down at predetermined limits as a function of the degree of deviation from the set point value or the plant stoppage time, e.g.:

- Gas temperature less than 900 ° C at kiln inlet,
- Temperature of material at kiln outlet less than 1250°C,
- CO- level above a value to be established by trial (Vol.%),
- Inadmissible control deviations in the set point/actual value comparison for the primary and secondary fuel feed,
- Raw-meal feed of less than 75 % of the max. possible quantity,

- Negative pressure before the exhaust gas fan below the value required at rated output,
- Permissible O2 level lower than inspection measurements require,
- Permissible NOx level above 500 mg/m³,
- Failure of burner,
- Dust level above permissible limit.

6 Monitoring - Emissions

A distinction is made between continuous measurements and individual measurement. A further distinction is made between first-time and repeat measurements, function tests and calibrations, and measurement for special reasons, e.g. to determine the emissions of exhaust gas components which are not continuously monitored.

The measurement-relevant parameters to be considered in measurement planning derive from regulatory requirements, e.g. the operating permit, information from the technical supervisory body responsible for the plant and from on-site inspection.

All emission measurement results are reported in g/m³, mg/m³, ng/m³ as the mass of the emitted components related to exhaust gas volume at standard temperature and pressure conditions (273 K, 1013 hPa), after deduction of the water vapour content. Typical kiln exhaust gas volumes expressed as m3/tonne of clinker (dry gas, 273 K, 1013 hPa). O2-content is normally 10 %.

To accurately quantify the emissions, continuous measurements are recommended for the following parameters:

- exhaust volume (can be calculated but is regarded by some to be complicated),
- temperature,
- Total dust,
- Hg (Mercury and its compounds)
- CO (Carbon monoxide), O_2 volume concentration
- NOx (Nitrogen oxides)
- SO_2 (Sulphur oxides)

Regular periodical monitoring is appropriate to carry out for the following substances:

- metals, semi-metals and their compounds,
- TOC (Organic substances)
- HCl (Hydrogen Cloride),
- HF (Hydrogen Fluoride)
- PCDD/Fs (Dioxins and Furans)

Measurements of the following substances may be required occasionally under special operating conditions:

- BTX (benzene, toluene, xylene),
- PACs (polycyclic aromatic hydrocarbons), and
- other organic pollutants (for example chlorobenzenes, PCB (polychlorinated biphenyls) including coplanar congeners, chloronaphthalenes, etc.).

1.1 Emission ranges

The use various secondary fuels is always accompanies by extensive emissions measure-ment. The most important results from these measurement are summarized in table 1. The emission ranges within which kilns operate depend largely on the nature of the raw materials, the fuels, the age and design of the plant, and also on the requirements laid down by the permitting authority.

Components [mg/m³]	**Emission value:** from - to	**Limit in permits** in Germany
Dust	1 – 15	14 - 20
HCl	0,3 – 5	10
HF	0,1 – 2,0	1
SO_2	100 – 400	350 - 400
NO_x	300 – 600	500 - 800
Hg	0,005 - 0,03	0,03 - 0,05
Cd + Tl	< 0,001	0,05
∑ Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn.	< 0,002	0,05
PCDD + PCDF (TE) [ng/m³]	0,001 - 0,01	0,05 - 0,1

Table 1: Emission in the exhaust gas from cement kiln

7 Conclusion

Existing measuring results concerning the use of 50 - 75 % alternative combustibles and wastes (calorific value from 18 - 25 MJ/kg) have proved that the pollutants will be burnt safely if the liquids are screened and the solid waste-derived fuels (for example polychlorinated hydrocarbons) are spread in the gas flow. With regard to the emissions of chlorinated compounds such as PCB and dioxin, the exhaust values of the cement rotary kilns can only be achieved in other burning processes by the means of large-scale after-cleaning equipments.

For the assessment of waste utilisation which is harmless and in compliance with the regulations it is necessary to take into consideration the Ordinance on Incineration Plants Burning Waste and similar Substances (17. BImSchV) provided that residues materials are used based on the EU Directive 2000/76/EC on the incineration of waste of 4 December 2000, German Clean Air Standards -TA Luft 2002 and the Recycling and waste Act.

This means that in the authorization application all wastes, or groups of wastes which can be grouped together, must always be specified individually with the relevant point of generation and analysis values as well as the calorific values. This requirement is particularly important when "synthetic fuels" are blended from various wastes outside the cement work.

Evaluation based on the criteria of anticipated emissions, conservation of resources, energy balance and build-up of pollutants requires a comparative examination of the environmental effects of the individual waste.

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Parallel session
Innovative energy efficiency examples of different industrial sectors - Energy efficiency in the cement, metal and petrochemical industry

FROM 167 GWH TO 72 GWH – VENTILATION ON DEMAND IN LKAB'S IRON ORE MINE, MALMBERGET

P. Nensén and A. Lundkvist*
**Corresponding author, LKAB, 98186, Kiruna, email: Anders.Lundkvist@LKAB.com*

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P. Nensén and A. Lundkvist*, **Corresponding author, LKAB, 98186, Kiruna, email: Anders.Lundkvist@LKAB.com*

ABSTRACT

The Swedish mining company LKAB is the major producer of iron ore within the EU. LKAB produces high performance iron products for steel manufacture, mainly in Sweden and elsewhere in Europe, but also in the Middle and Far East. The company has three production sites and operates two underground mines located in Malmberget and in Kiruna, in northern Sweden. The annual energy consumption in the company is close to 3000 GWh, of which 350 GWh are used in the mines.

An advanced, energy-intensive ventilation system is necessary in the mines to ensure a good working environment by regulating air temperature and removing gases emitted from vehicles and blasting, other harmful gases such as radon as well as dust. The ventilation system in Malmberget consists of nine primary stations for providing fresh air into the mine and ten stations for the extraction of exhaust air. Primary fans and ventilation shafts are used to take fresh air into the mine and secondary fans, together with flexible ventilation ducts, distribute the air into the production drifts. A total of 130 secondary fans are used in the Malmberget mine.

Initially the fans in the primary shafts forced the heated fresh air into the mine and forced the polluted air from the production areas of the mine into the used-air shafts. The fans were controlled manually and operated 24 hours per day. The first step in the improvement of this system was to introduce partial time-control of the ventilation equipment.

Today, the amount of ventilation in specific areas of the mine is demand controlled. Fans in the secondary systems are controlled according to signals from carbon monoxide sensors in the mine and transmitters on the mine vehicles. The identity and properties of the vehicles are known and the fans are adjusted to the specific ventilation needs generated by each vehicle in the mine. This affects the air pressure and the primary fans are controlled according to the output of sensors which measure pressure drop.

The result of this work was a 29 % decrease in energy consumption of the fans and a 40% decrease in energy for heating the mine air. The introduction of this new system and other modifications in the Malmberget mine have led to a decrease in the annual electrical energy consumption from 167 GWh to 72 GWh.

1 Introduction

The Swedish mining company LKAB is the major producer of iron ore within the EU. The annual production of iron ore products was 22 million tons in 2003. Customers are big steel making companies in Sweden and elsewhere in Europe, as well as the Far and Middle East.

Mining, ore dressing, pelletizing and transporting iron ore involves several energy intensive operations. The annual energy consumption in the company is close to 3000 GWh, of which 1500 GWh is electrical energy and the rest comes from fossil fuels. The electricity is mainly used in processes like the hoisting of ore, ventilation of the mines and the comminution and grinding in the mineral processing. Coal, oil and diesel are used in the pelletizing plants and by trucks and other vehicles.

The annual energy usage corresponds to 10 % of the running cost of the company and was, in 2003, close to 60 million Euro. The development of the mines is toward greater mining depths and a higher degree of refinement. This is necessary in order to remain competitive but gives rise to increased energy consumption and higher costs.

LKAB, therefore, makes great efforts in adopting measures for increasing energy efficiency. The development of the new ventilation system in Malmberget mine is a good example of such measures, which have multiple benefits: decreased energy consumption, lower running costs, better internal and external environment. This paper describes this project in more detail.

2 Background

2.1 Ventilation in the Mines

The purpose of ventilation in the mine is to maintain an environment which makes it possible to work underground. The removal of air contaminants from the mine is as much a prerequisite for underground production as is the pumping of water. An aspect of particular focus at LKAB is accessibility to production areas; the availability of ventilation in the mine is an essential part of this.

Operating in an environment where air quality is challenged by gases, dust, moisture, and in some cases, high or low temperatures places great demands on the ventilation system, among other things. Exposure to poor air quality is dangerous to human health, thus the aim is always to keep contaminant levels as low as possible.

It is primarily blasting, loading and transport which contaminate the air in the mine. In conjunction with blasting, most of the gases formed from the explosions end up in the surrounding air volume. However, part of the gas volume is trapped within the rock piles; the amount of which depends on factors such as the type of explosive used, the size and structure of the blasted rock and moisture levels. Such gas can remain occluded in the rock-piles for long periods. Gaseous explosion products are mainly carbon dioxide, nitrogen and water vapour; most of which are considered as non-toxic. Besides these gases, there are a number of others with varying degrees of toxicity. The most dangerous of these is carbon monoxide. Varying quantities of nitrogen oxides (NO_x) are also encountered.

Besides carbon dioxide and water vapour, diesel exhaust gases contain several different chemical contaminants – many of these with high toxicity such as carbon monoxide, nitrogen oxides, polycyclic hydrocarbons and some aldehydes.

Figure 1. Mine vehicles such as diesel front-loaders and large trucks inrease the need for effective ventilation.

A vast amount of dust is generated during mining operations. The chemical nature of the dust and its particle size are important factors, which determine how harmful dust is to human health. Dust may be categorised as either *active* or *inactive* – quartz dust is an example of active dust, which can cause silicosis.

Radon is another significant concern in our mines. When radioactive radium decays, radon – a noble gas - is formed. From radon, radioactive daughter products are formed which readily attach to aerosols, which can be inhaled. Radon and the daughter products are toxic and exposure can cause lung cancer. Radon in the mines originates mainly from water draining into the mine and leaching from fixed rock surfaces and blasted stone.

2.2 Occupational exposure limits

The nature of air contaminants (such as those discussed above) and the length of exposure are what dictate the likely health effects of exposure. When setting targets for air quality in the mine the concept of *occupational exposure limits* was used. These are the maximum concentrations that can be considered "acceptable" for predefined periods of exposure. These are often expressed in units of parts per million (ppm) or mg/m^3. Guidelines for the different exposure limits for various contaminants have been established by the Swedish Work Environment Authority's *Provisions on Occupational Exposure Limit Values (AFS 2000:3)*, the following definitions and limits (table 1) are relevant for the most commonly encountered measurements at LKAB:

- **Occupational exposure limit value, OEL –** this is the maximum (time-weighted) average concentration of an air contaminant in respiratory air. The contaminant may be a single substance or a mixture. An OEL value is either a level limit value or a ceiling limit value.
- **Level limit value, LLV –** this is an occupational exposure limit value for exposure over a whole working day (8 hour shift).
- **Ceiling limit value, CLV –** is an OEL value for exposure during a reference period usually 15 minutes (or less for reactive of very toxic substances).
- **Short-term value, STV –** is the recommended value consisting of a time-weighted average for exposure during a reference period; usually 15 minutes.

Table 1 - Summary of exposure limit values for some relevant gases and dust

Contamimant	LLV	CLV
Carbon monoxide, CO	20 ppm	
Nitrogen dioxide, NO_2	1 ppm	
Ammonia, NH_3	25 ppm	50 ppm (5min)
Respirable dust (general, unspecified composition)	5,0 mg/m^3	
Total dust (general, unspecified composition)	10,0 mg/m^3	
Respirable quartz dust	0,1 mg/m^3	

Additionally, the Swedish Work Environment Authority's *Provisions on Occupational Exposure Limit Values (AFS 2000:2)* gives limits for the climate in mining workplaces; these are summarised in table 2.

Table 2 - Summary of relevant limits for climate in a mining workplace

	CLV	STV	Target in workplaces
Carbon dioxide, CO_2	5000 ppm	10000 ppm	1000 ppm
Temperature			20 ^{0}C
Relative humidity			40-60 %

Radon: For work underground, the limit value is 2.5 MBqh/m^3 per year. For 1600 hours under ground per year this corresponds to a level of approximately 1500 MBq/m^2. This level applies to the measurement of radon gas or radon daughters. There are factors (according to the Swedish Radiation Protection Institute) which may be used to estimate the relationship between radon gas and radon daughters.

3 Mining Operations in Malmberget

The mine in Malmberget consists of about twenty ore bodies, of which ten are currently active. The main transport levels in the mine are at 350, 600, 815 and 1000 meters below the surface and give access to reserves estimated to extend at least to 2011.Most of the deposits are of magnetite ore, although deposits of hematite ore are also found and have been mined again since 1998. During ore refining and the production of blast-furnace pellets, 10% hematite ore is blended with magnetite ore.

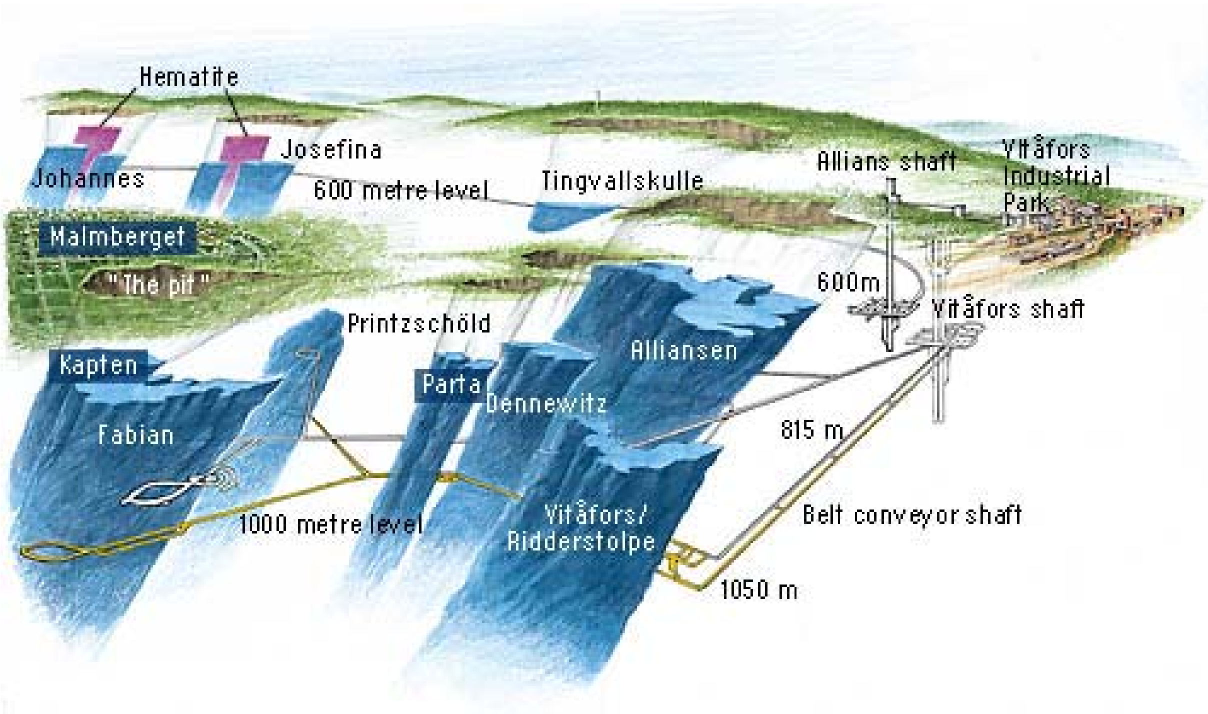
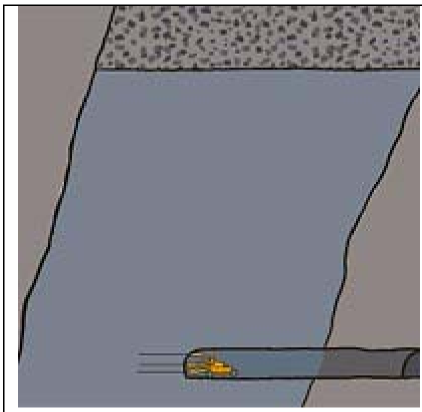
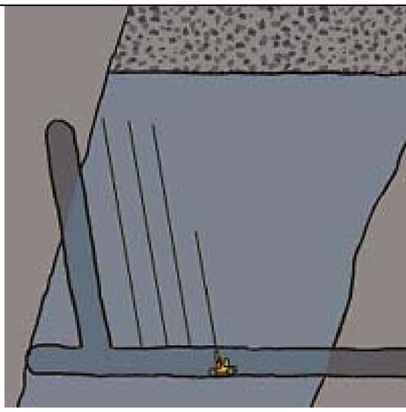
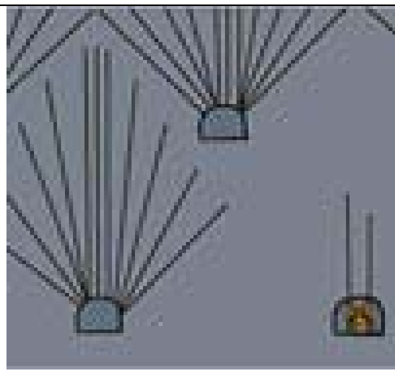


Figure 2. Ore bodies which are the basis for LKAB's Malmberget mine

Large-scale sublevel caving is a flexible and relatively save method for mining ore and is the main method used in LKAB's mines. The process consists of a number of phases, which are depicted, in figure 3 below. The first phase of *preparation* or *development* is the accessing of new sections of the mine by the blasting of dead-end tunnels or drifts into the ore body. From the development drifts production drilling is carried out. By drilling upwards from the development drift, a number of slightly sloping, fan-shaped 'slices' are made with regular spacing – this is *production drilling*. *Charging and blasting* is carried out 'slice by slice' – explosive is injected into the drill holes of a fan-shaped array and detonated, after which the area must be ventilated before *loading* of the ore can start. Large loaders move the ore to vertical shafts or ore passes. The load of about 17-25 tons drops down the ore pass into bins just above the nearest main transport level at 600, 815 or 1000 m. *Haulage* in the transport level is by trucks which are loaded from the vertical shafts. Drivers control loading from inside the cab of the truck. The fully loaded truck is then driven to a discharge station and the ore is emptied, sideways, into a crusher bin. This is also controlled from the cab of the truck.
The ore is fed into the crusher and crushed into lumps of about 100 mm in diameter. From the crusher, the ore is conveyed to a skip shaft and *hoisted* to the surface.

 Preparation, development	 Production drilling	 Production drilling (different projection)

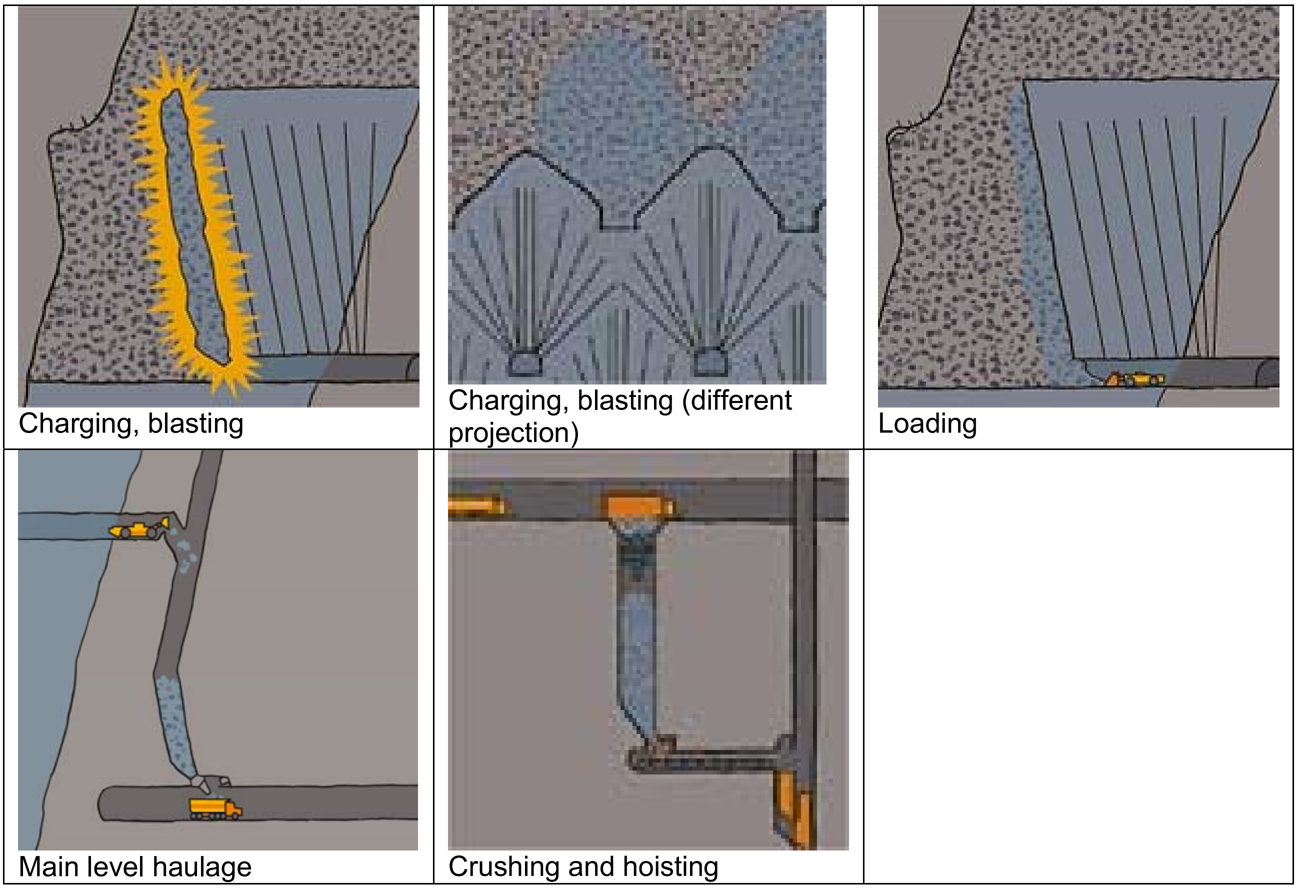


Figure 3. Phases in the mining of iron ore in Malmberget using large-scale sublevel caving

4 Previous Ventilation System

The ventilation system is essential for ensuring a safe working environment in the various phases of production. Two main ventilation principles are usually applied for minimising environmental problems associated with contaminants:

- dilution, where clean air is introduced at the same time as the polluted air is evacuated. The aim is to dilute contaminant concentrations to below their relevant limit values.
- extraction, on the other hand, focuses on removing the contaminants at their source (using extraction hoods, for example) before they can mix with the surrounding air volume.

Mine ventilation usually consists of primary and secondary ventilation systems. The primary system serves to convey air to and from the mine and consists of underground installations such as shaft and tunnel systems. Ventilation walls and primary fan stations are also part of the primary system.

Figure 4. Extraction station (primary system)

Figure 5. Fresh air ventilation wall (primary system)

The secondary system consists of fans and associated ventilation tubing and ducting which may be adapted to suit the future activities within specific areas of the mine.

Figure 6. Secondary fans installed within a ventilation wall (fresh air supply)

The original underground ventilation system in Malmberget was planned and built starting from the beginning of the 1960's up to the mid 1970's. The most recent fresh air shaft to be completed was Dennewitz F9B in 1975. The system was thus planned and adapted for mining activity down to a depth of only 600m.

When the transport level at 815 m was established in 1987, the existing ventilation shafts were extended from 600m. Over the years the ventilation system has been further adapted and extended on a number of occasions to accommodate changes in production. Even modifications to the distribution system have been made due to leakage into areas of caving or damage from blasting.

<u>Factors motivating the installation of a new system</u>

The ventilation system as it was suffered from some serious shortcomings. Short-circuiting of fresh and extracted air resulted in large volumes of air needing to be circulated. Despite these volumes and the associated high energy consumption, air quality and thus the working environment was poor, which led to increased disturbances to production. As is the case today, the ventilation system was made up of fresh air stations and extraction stations, however, without any regulation. The ventilation shafts were not continuous but consisted of a “staircase” of vertical shafts between each 20m level with some (varying) horizontal offset between each shaft. This gave rise to significant backpressure in the system, and much of the fresh air followed the lowest pressure, which was into the extraction system. The existing system also suffered from problems with leakage between levels at 350 m and 600 m, which led to high heating costs.

The result of all this was that all the fans were running at maximum capacity, large volumes of fresh air were being heated yet still insufficient air volume of insufficient quality were reaching the areas where it was needed. Airing and extraction of explosion products, diesel gases and dust were also insufficient for attaining acceptable levels for accessing production areas (within acceptable time scales).

5 The new Ventilation System

Disturbances to production, interruption to loading etc which resulted from insufficient ventilation and the projected needs for the new 1000m level prompted the decision to build a new ventilation system in the Malmberget mine. The new system *Vent 2000* was taken into operation during 1999- 2000. An overview the system is shown in appendix 1. A single primary fan station was built with 2 fans, each with a capacity of 350 m^3/s. These are driven by 1.3 MW, variable-speed electric motors. Air is distributed via two drilled shafts with diameters of 4.5 m.

These shafts take in air from the surface down to 840 m where it is distributed to various areas in the mine via bored, 2-5 m diameter secondary shafts. From these shafts air is pushed, via secondary fans, to the ends of the production drifts. Extraction is via fans mounted in extraction walls and extraction stations with raise the pressure of the air for transport up to the surface..

Figure 7. Fan installation at Dennewitz

Figure 8. Air intakes for primary shafts (4.5 m diameter)

5.1 Construction and installation

The investment in the new ventilation system can be divided into the following five phases:

- Installation of an air intake into the existing primary system from Kapten’s boiler facility. A ventilation shaft was drilled and connected to the existing transport drift at 500m between Uppland and Kapten. Raise boring of a 3.5 m diameter air supply shaft and the installation of an auxiliary fan (for raising the pressure) for the ventilation of Printzsköld to

820 m and future increases in depth. This phase included construction work such as foundation, fan walls, doors etc. The installation has a capacity of 250 m³/s and is equipped with need-based control from BEVUJ (described in more detail below).

- Installation of a primary air supply, consisting of two 4.5 m diameter raise bored shafts, from Dennewitz' surface to the new distribution level at 840 m. At the distribution level, a secondary system of shafts supplies fresh air to Alliansen, Vitåfors/Ridderstolpe, Parta, Dennewitz and the smaller Eastern Mine. At the end of the drifts, in Vitåfors/Ridderstolpe, Parta and Dennewitz, barrier walls with doorways have been installed. In Alliansen a manually operated drive-through and a walk-through doorway have been installed for easier access to the system for inspection and service.

- At Dennewitz' surface a new fan station (2 x 1300 kW) with was installed with a fan capacity of 2 x 350 m³/s and equipped with heat exchangers for heating the air. The capacity of the boiler facility has been increased from about 12.3 MW by the addition of an oil-fired boiler of 6 MW and an electrical furnace of 0.3 MW giving a total output of approximately 18.6 MW. As a result of this capacity increase and the discontinuance of production at Tingvallskulle, the Uppland boiler facility could be closed-down. The fan station is equipped with pressure drop measurement at level 840 m as part of the regulation of the primary fans in the need-based control system (BEVUJ).

- In total 7 air supply and 5 extraction channels connect the distribution level (840 m) to the new transport level at 1000 m (M1000). As the construction of M1000 progresses, these channels will be connected to the new production levels. Fabian is not yet connected to a secondary system but work is currently underway to connect this to the need-based system (BEVUJ).

- An approximately 1000 m long tunnel system at the 820 m level has been constructed for the production areas of Printzsköld and Hoppet. Parts of these are now in use for preparation and development work and as secondary ventilation for M1000.

In addition to the above installations, parts of the previous system remain in use for ventilation. Parts of the previous fresh air supply system are now built into the extraction system for transporting exhaust air up to the surface.

As a result of the new installation, new possibilities were opened for monitoring and controlling the facilities. The primary system must ensure a pressure differential in the mine's ventilation, which depends on how many secondary fans are in operation. Thus, in order to optimise the operation of the primary fans, the secondary fans also need to be regulated.

5.2 Need-based mine ventilation (BEVUJ)

LKAB has developed need-based ventilation in order to optimise the use of air, provide a good working environment yet minimise energy consumption. The BEVUJ control system is currently supporting mining operations at Alliansen, Dennewitz, Parta and Vitåfors /Riddarstolpe (Eastern Field) and installation is underway in the Western Field. The control units are mounted in an electrical container for the fan units and thus follow the mining activities as they progress downward. Each new installation requires only the laying of telephone cable from the carbon monoxide sensors and transmitter-receivers to the control unit. Repairs or replacement of the remote equipment can be carried out rapidly and at low cost in the event of damage from blasting or other activity. Frequency inverters (50 to 60 Hz) fitted to the fans increase output pressure and flow capacity by about 17%.

Figure 9. High pressure blower

Figure 10. Fan control units with frequency inverters.

The fan units have been modified for variable speed operation with the capability for local, time-controlled override. There are sensors for the detection of CO and transmitters and receivers for the distribution of signals. This is all steered locally from microprocessor control units, which means that in the event of failure of or disconnection from the main system, the local units will still function according to their default settings.

The fans are started and stopped according to CO sensor measurements or by radio transmitters mounted in the mining vehicles and machinery. If the CO levels exceed preset levels, the fans are started automatically irrespective of what time of the day it is. The machine mounted transmitters also activate the local fans 1-2 minutes after contact with the local receivers.

Each vehicle that is used in the mine is equipped with a transmitter with its own identity. This enables ventilation to be adapted according to the needs of each particular vehicle or machine. For example, when a diesel loader enters a particular area, fans in the area respond with full effect whereas an electrical loader in the same area only requires 20% of the maximum ventilation capacity.

The system can be controlled from a control room, by timers or completely automatically. The control system enables monitoring of each fan installation in the mine and information on operation and energy consumption is displayed on process diagrams. Fuel consumption and CO_2 emission data are also logged and can be used for emissions estimates, environmental reporting etc.

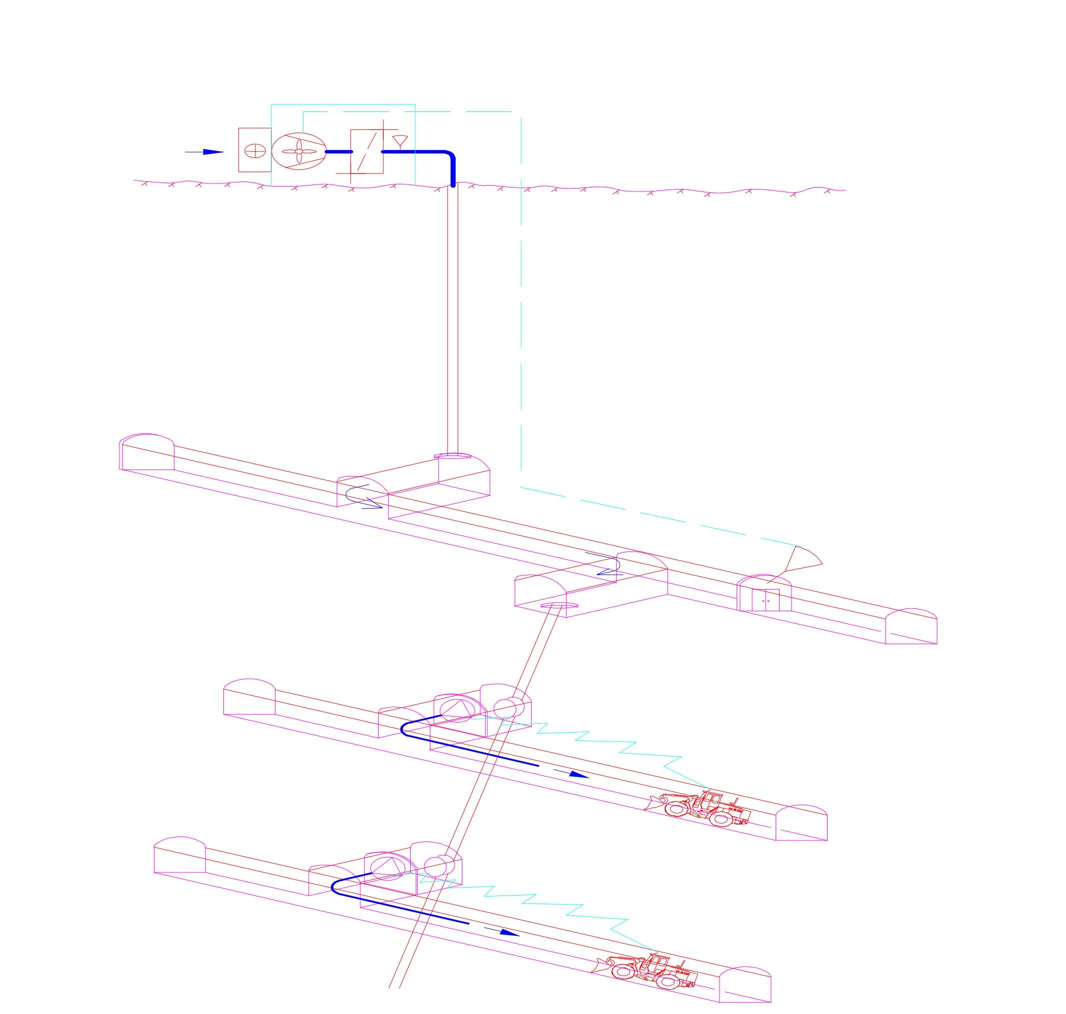


Figure 11. Functional overview of BEVUJ showing the primary fan station and boiler facilities at the surface. Three underground levels are shown with a spacing of about 30 m between them. The first level from the top is the distribution level at 840m. The transmitter shown in the distribution level is part of the pressure differential measurement, which controls the operation of the primary fans. In the two lower production levels the secondary fans, mounted in a fresh air ventilation wall, are controlled by transmitters in the production machinery and by CO sensors.

6 Significance of the new System

The need-based control system gives the ability to steer the supply of fresh air to where it is needed. Frequency adjustment of the fans, to 60 Hz, increases airflow and pressure drop, which increases the effectiveness of the secondary system. Primary fans are started and stopped based on the number of secondary fans active, enabling balance between primary and secondary systems.

In the new system, individual fans can be monitored online and continuously which increases system availability and gives greater potential for optimising operations. Energy consumption in each part of the system can be recorded which means that maintenance can also be optimised.

The system can be steered from a central control room allowing flexibility in meeting the needs of production. Local control with timing and time-delay is also possible.

The system is flexible and the existing telephone network is used for system communications.

6.1 Energy consumption

Since the introduction of the new ventilation system the total flow of air in the mine has decreased – instead of fans operating around the clock, operation is now controlled. This has resulted in a considerable decrease in the use of electricity and oil for the heating of air (see figure 12) and significant reductions in fan energy consumption (figure 13).

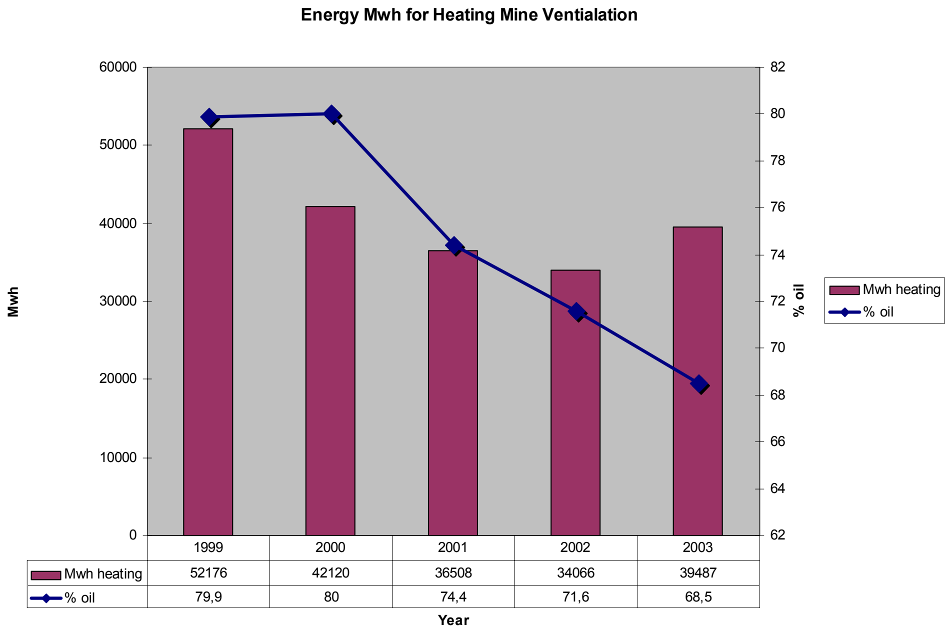


Figure 12. Development of heating energy requirements since 1999

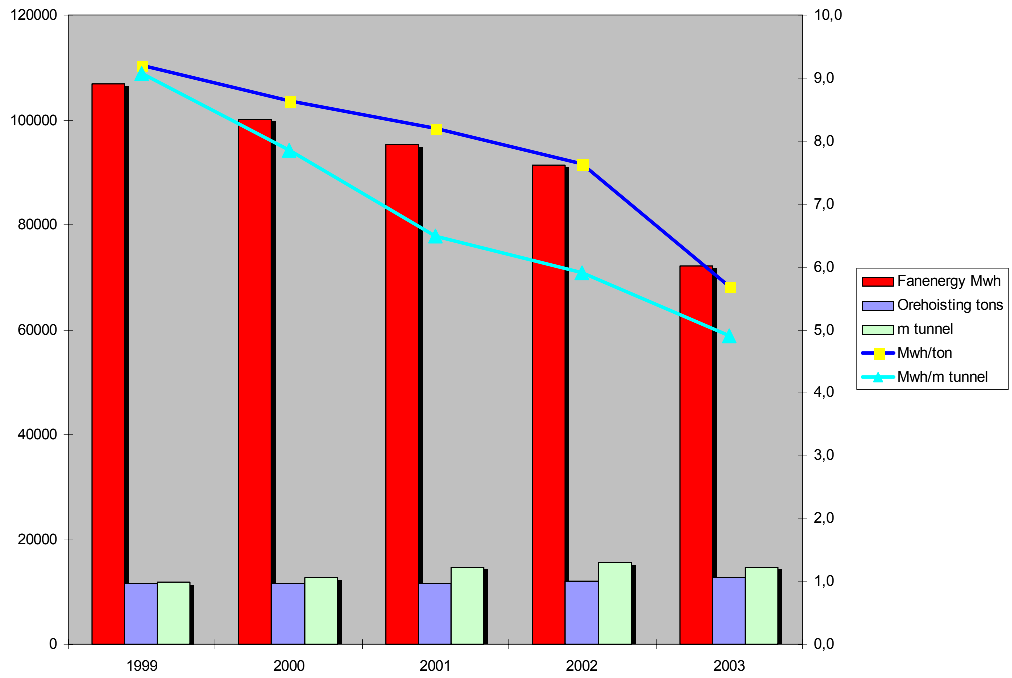


Figure 13. Development in ventilation fan energy requirements since 1999

6.2 Environment

By steering the flow of air to where it is needed, together with the ability to introduce a greater air volume and more effectively extract exhaust air implies significantly reduced levels of contaminants in the air and an improved working environment. The reduced overall energy requirements are of course significant for the external environment.

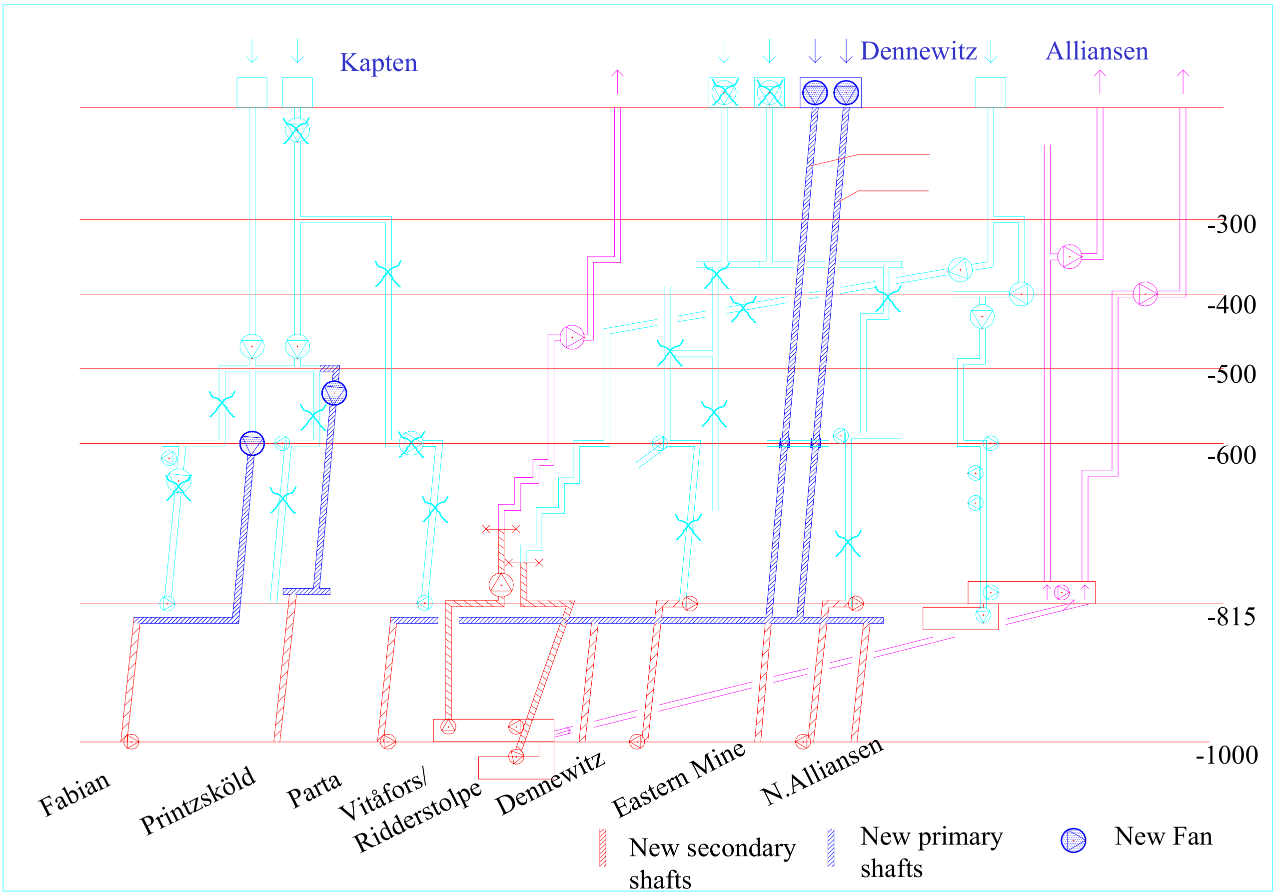
6.3 Economy

The total investment in the ventilation system, was about a € 0.5 million including development costs. The most recent installation in the Western Field and Printzsköld cost an additional € 0,25 million. The energy savings of 54000 MWh per year imply a payback time of 1.3 years for the more recent investment.

7 Conclusion

When mining at LKAB's Malmberget mine made the transition from open caste to underground mining, ventilation became necessary. This consisted of fixed-speed fans with manual start-up and shut-down. As the mining operations grew, ventilation channels and boiler facilities for warming the air were needed and installed. From the 1950's to 70's oil and electrical energy were relatively cheap, besides which, techniques for the speed control of fans were not fully developed. With time, the need for more effective use of energy has grown, as have the demands on a good working environment. In the late 1990's the drilling of ventilation channels and tunnels for a new ventilations system started. In order to achieve the goal of the best possible working environment in an energy-effective manner, a need based mine ventilation system (BEVUJ) was developed. Here the primary and secondary systems are steered according to the local needs of separate production areas.

Appendix 1. Overview of mine ventilation system



Parallel session:
Innovative energy efficiency examples of different industrial sectors –
Energy efficiency in the cement, metal and petrochemical industry

PROCESS MEASURES IMPLEMENTED INTO AN IPPC NODULAR IRON FOUNDRY, LARGE SERIES AUTOMOTIVE CASTING PRODUCER, TO INCREASE ENERGY EFFICIENCY USE

Mário Palmeira, Miguel Oliveira, Américo Machado Cunha, Carlos A. Silva Ribeiro
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ABSTRACT

In this paper is described actions implemented into the PortCast – Intermet Porto nodular iron foundry in order to reduce the specific energy input into every casting sold.

These measures have been taken acting into the manufactures process – strict control over the melting process, increase of pattern yield, rejected castings reduction, efficient use of product development using CAD /CAE technologies and reducing the most important inefficient production factors.

An emphasis will be given of the environmental control measures upon energy consumption.

1 Introduction

PortCast-Intermet Porto foundry is an IPPC installation, located at Maia town, in the neighbourhood of the famous Porto town, because of the special wine and football team, at the north of Portugal. It is owned by Intermet Group, although its foundation goes back to the seventies, as a malleable iron producer. Since the end of the nineties it produces 100% nodular iron, perlitic and ferritic as cast grade, mainly large series of automotive light and medium size castings.

In the portfolio are several general types of automotive family castings, such as brake components, suspension arms, differential cases, bearing caps and general automotive casting, for most known end car producers.

This foundry has induction melting and holding electric furnaces, operates three high pressure green sand moulding facilities, two vertical parting line DISA and one horizontal parting line George Fisher machine, cold box core shop and eight semi-automatic finishing lines. It uses a very powerful and new informatics tool - DataPro® - developed in house, to control the overall process, since metal charging into the melting furnaces, the chemical and metallurgical process quality of the molten metal, sand quality, rejection causes and rate, finishing operations and delivery conditions. It has also a development product department, with CAD and CAE software to model, adapt and simulate the different lay-outs.

PortCast-Intermet Porto foundry has various quality certifications and environmental certification and is preparing the health and safety certification. Since 2000 is upgrading the environmental control systems with new and more powerful collecting and fume treatment systems, in order to fulfil the requirements of BAT document for foundries finished and released this year.

2 Foundry Process at PortCast – Intermet Porto Foundry

PortCast-Intermet Porto foundry is an IPPC installation, so it has to be operated in an efficient manner, in order to be competitive and fulfil the environmental requirements.

Melting is carried out using medium frequency induction furnaces, with an average melting rate of 16 ton per hour, or roughly 370 ton of molten metal per day. Charge preparation is computer driven and controlled and melting furnaces are charged automatically. Metallurgical adequacy is checked using thermal analysis and spectrometry, chemical corrections eventually made. When temperature is adequate, the slag is removed and the molten metal transferred to holding furnaces. There the Chemical composition is controlled in regular period of time, using spectrometry and thermal analysis and the metal is nodularized using a sandwich technique with 0.95% of 5.5% Mg, Fe-Si alloy and pre-inoculated with up to 0,3% of a proprietary Fe-Si.

The molten metal is then transferred to automatic pouring devices, where a last pos-inoculation (jet-stream) is made.

Thermal analysis play an important roll in the process control because it allows the early forecast of the sensibility of the molten metal to develop metallurgical deficiencies, such as cast carbides, graphite shape, perlite content and tendency to develop microporosity. The company use it, connected to DataPro® system, at the melting shop, at the holding furnace and at the pouring stations.

The core shop uses the cold-box process and has five core shooters: two with 16 litre, another two with 25 litre and one with 60 litre shooter volume capacity, able to make 225 cycles per hour or roughly 5000 cycles per day. The installation is equipped with an amina scrubber cleaning system and several dust collecting and treatment equipments.

Moulding has two vertical parting line DISAMATIC machines, with a SPACE sand plant able to process up to 100 ton of sand per hour, and a horizontal parting line George Fisher machine with a GF sand plant able to process up to 52 ton of sand per hour. These three moulding machines have the total capacity of manufacture roughly 50 000 ton of good castings per year.

To finish the castings, the company may use up to eight semi automatic finishing lines.

Figure 1 sketches a general process at a green sand foundry. There are two main streams: one for metal and another for sand. Metal goes from stockyard, through melting, holding and pouring. Sand goes through green sand preparation, core manufacture up to moulding lines. There metal and sand get together when molten metal is poured and allowed to solidify and cool, in order to shape it as a casting. At the shakeout area they split again.

From 100 % of poured metal at the moulding line, only a fraction could be sold as casting. Part is lost as metal spill (1 to 2%), another important portion as the feeding and runner system (up to 60%, but normally below 40%) and a small proportion is lost as scrap castings which does not match quality standards (normal figure is below 5%). The higher the overall yield, smaller will be the overall energy input into a sold casting.

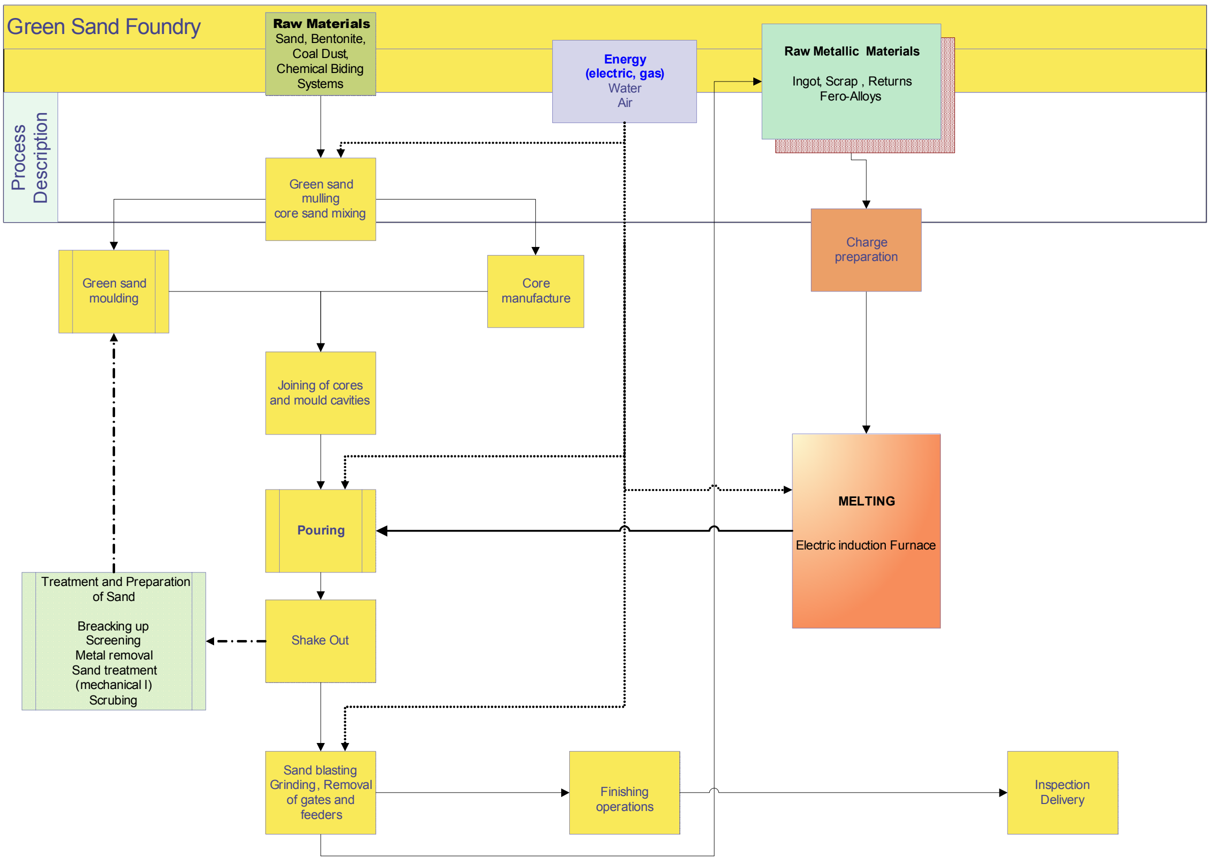

Figure 1: general process flow diagram for PortCast Intermet Porto: there are two main flow steams: one for metallic materials that start at the stockyard, go through melting furnaces up to moulding cavities, where the metal take shape during solidification and cooling of molten metal, and another the flow of sand, to make the mould cavities and cores

3 The use of energy at PortCast – Intermet Porto Foundry

PortCast-Intermet Porto foundry use electric energy as the main source energy and, at a small proportion, natural gas (mainly to preheat ladles, furnaces and other equipment). Electric energy is used for melting the metal up and also for the other machines (drive motors and to produce compressed air).

Electric energy comes to the company at a 60.000 kV.
The energy cost influence into the casting price depends upon three factors:

(a)– How energy is used during the day, because the kWh price is a function of installed power and the day by day profile cycle of energy use;
(b)– How the installation is operated, mainly at the melting shop, because it is the main energy consuming;
(c)– Overall metal yield.

A very meticulous study has been carry out in order to identify the best energy use cycle: it has several sub-cycles, that goes from empty hours at night, between 21 and 8 h in the morning, up to peek hours, from 9.30 to 11.30 and from 19 to 21 in the afternoon. The price fluctuates from winter to summer time.

After this study, a decision was made in order to avoid melting during peek hours. Moulding lines should use molten metal from holding furnaces, which may supply around 40 ton. Whenever possible, light weigh castings should be made in that period of time.

When the pattern yield increases (proportion of castings made from poured metal per mould) and scrap rate decrease, metal yield increase and the overall process yield increases. As a result, the energy input, per sold casting, decreases and the company becomes more competitive.

The more energy consuming part of a foundry is the melting plant, where solid metal is transformed into molten metal, which after chemical and temperature adjustment it is poured into mould cavities to give a shape to castings. Quick melting operations at lower superheating (maximum molten metal furnace temperature and holding time) will give rise to the use of smaller quantity of energy per good casting produced.

In a thorough study of energy consumption at the company, during year 2000, gave four big families of energy distributions, which the practice should be carefully followed:

1st – **Melting plant**: **75%**
2nd – **Sand plant**: 6.3%
Dust collecting and treatment system: 5.9%
Total **12.2%**
3rd – **Compressed air**: 3.8%
Finishing operations: 3.5%
Moulding and core shop: 3.1%
Total **10.4%**
4th – auxiliary operations
Stockyard: 0.9 %
Water cooling system: 0.9%
Lightning and others: 0.6%
Total: **2.4%**

Any action taken to reduce the energy consumption at the melting shop will be welcomed. For instance, a 5% decrease on the melting energy will reduce 3.75% of the overall energy consumption.

Two aims have been set:

(a) – Take measures to decrease the energy used in the melting operation;
(b) – Improve the pattern plate yield, because this last one will free metal, from melting shop, to be used to manufacture more castings without increase melting capacity.

A comment should be made upon the influence of the installation and running of pollution abatement equipments. PortCast Intermet Porto is ISO 14000 certified and is under IPPC requirements. New and more efficient pollution control equipments have been installed along the past years. Besides the huge investment and running costs, this effort has a stamp on the energy consumption, which could be accounted for up to 6% of the energy, per ton of casting sold. This figure is about to increase because of new dust control and treatment equipment to be implemented along with the new melting installation, just installed. Environmental authorities should be alerted to this reality in the moment to issue permits.

4 Actions taken into melting shop

The theoretic energy needed to melt and superheat, up to 1500 ºC is roughly 307 kWh♣. The exact value is of no special interest, because specific heat is not known with precision, varies with temperature, and the influence of the melt composition is very difficult to anticipate. This value is only an indicative figure of how far could the energy consumption goes down.

Heat and energy loss, takes place by:

(a) – the water cooling system,
(b) – by radiation from the top of the molten metal and
(c) – by lengthy operation procedures of filling the furnace, removing the slag, correcting the melt composition and collecting samples to check chemical composition or perform thermal analysis tests.

International surveys make the following references to energy consumption benchmark values, to melt or produce a ton of molten metal or good castings:

1st – IPPC reference document on Best Available Techniques for Smitheries and Foundries (July 2004) refers a value between 520 and 800 kWh per ton of cast iron melted, considering a thermal efficiency around 50 to 60% (table 3.1 page 98);

2nd – Energy Use in Selected Metalcasting Facilities – 2003 – Eppich Technologies, February 2004, for the USA Department of Energy, quotes a value which varies according the type of foundry and operation, around 1794 and 1930 kWh per ton of sold casting (page iv). For a small 5000 ton per year nodular iron foundry the total electric energy quoted is 2502 kWh (page 37, table 3.48). 88% is said to be used in the melting operation, so a rough number would be 2202 kWh per ton of casting sold. In this very same study, a figure of 2113 kWh/ ton good casting is referred for 150 000 ton per year of ductile iron castings foundry;

The study concluded that a fair number would be about 550 kWh/ ton of molten iron melted, although nothing is said about superheating temperature and the type of the metal stock.

♣ American Foundryman Society Transactions 02-146 pag. 1-10; "*Thermophysical Properties of 201 Al, Ductil Iron and Sebiloy II*"; http://metalcasting.auburn.edu

3rd – The Bureau of Natural Resources of Canada – Energy Benchmarks in Foundries, quote a value of 2395 kWh of energy (or 1555 kWh of electricity) per ton of good casting. The benchmark value per ton of molten metal is 992 kWh.

A target was set into PortCast Intermet Porto, so that the melting energy goes below the 650 kWh per ton of molten metal, and the total energy approaches or goes even down the 2000 kWh per ton of sold casting.

A steering group of people was charged to implement ideas how to reduce the consumption of energy on the melting shop. In the end they come up with a set of recommendations:

- Use denser metal charge to start melting operations in each furnace – use of denser metal charge, in the form of packed steel foundry scrap, up to attain a molten metal heel. Light or thin foundry scrap needs more energy to achieve the same temperature.
- Addition of Ferrous Alloys only when there is a molten heel
- Control of when the slag should be removed
- Superheating control: temperature and time
- **Swift removal of molten metal** from furnace
- **Control of Temperature in holding** furnaces
- **Use of Clean Foundry Returns** (stripped from sand): adhered sand will consume energy to create and to make a fluid slag
- Swift control of **chemical** and **metallurgical quality** of the molten metal

All these measures were implemented after specific training actions of the staff from melting shop

Actions taken to increase metal yield and reduce scrap rate

An increase in the metal yield could be done acting in the pattern plate yield and a decrease in the scrap rate.

The aim of increasing pattern plate yield could be done in two different ways: by a trial, analysis and correction of errors or using solidification simulation software.

The trial and error method is expensive and time consuming, because every change in the pattern layout needs to be experimentally validated.

Another method is to validate the use of solidification simulation software, which this company have done, by setting up a product development group with broad aims to increase pattern yield of new castings and of current production, acting on the gating layout and improving the feeder yield.

Castings need to be “fed” during solidification. Mould cavities are full with superheated molten metal, which contracts upon cooling and solidification. Risers, or feeders, are projected according scientific and technical principles, but the useful metal which might be use to “feed” castings varies between 15%, for normal feeder used into green sand automatic lines, up to 65% when aiding sleeves might be employed. But feeding aids are seldom used in automatic lines with high production rates. So is very important to have some sort of tool which might enable to adapt the feeder location and geometry, in order to increase feeders yield.

This has been the use made of simulation software at this company: simulate, adapt and improve the molten metal use, before actually test and produce castings.

Evolution of the pattern plate yield in the past years

Year	2001	2002	2003	2004
Pattern plate yield	42%	46%	50%	> 52%

5 Concluding remarks

Serious efforts have been made to decrease and keep low the scrap rate value. The home made software tool DataPro®, had enable to control of the most important production parameters and acting immediately, by the operator, if any parameter is going to the limits of the range It is also possible to track changes along time.

This tool, along with careful planning and practice of melting operations and actions taken to increase pattern yield enable reduce the energy input per casting sold, as shown in the next table.

It was possible to reduce the energy input from 2513 kWh per ton of good casting sold, in the year 2000, to 2000 kWh in this year. The installation of new melting furnaces might give the hope of near future reductions in the energy input.

Parallel session
Innovative energy efficiency examples of different industrial sectors -
Energy efficiency in the cement, metal and petrochemical industry

ENERGY EFFICIENCY AND INNOVATIVE EMERGING TECHNOLOGIES FOR OLEFIN PRODUCTION

Tao Ren, Martin Patel and Kornelis Blok
Department of Science, Technology and Society,
Faculty of Chemistry, Utrecht University,
Heidelberglaan 2, 3584 CS, Utrecht, The Netherlands

ENERGY EFFICIENCY AND INNOVATIVE EMERGING TECHNOLOGIES FOR OLEFIN PRODUCTION

Tao Ren*[*]*, Martin Patel and Kornelis Blok, *Department of Science, Technology and Society, Faculty of Chemistry, Utrecht University*

ABSTRACT

Among the current IPPC installations, steam cracking for olefin production is the single most energy consuming process (ca. 30%) in the chemical industry, accounting for ca. 180 million tons of CO_2 worldwide. This paper reviews steam cracking and innovative emerging olefin technologies in terms of energy efficiency. Pyrolysis section alone consumes ca. 65% of the total energy use and ca. 75% of the total exergy loss. An overview of state-of-the-art naphtha cracking technologies shows that ca. 20% savings on the current average energy use are possible. Advanced naphtha steam cracking technologies in the pyrolysis section (e.g. advanced coil and furnace materials) may together lead to up to ca. 20% savings on the total energy use by state-of-the-art technologies. Improvements in the compression and separation sections may together lead to up to ca. 15% savings on the total energy use by state-of the-art technologies. Catalytic olefin technologies could possibly save at least ca. 20% on the total energy use by the state-of-the-art naphtha steam cracking.

Keywords: energy efficiency, energy analysis, steam cracking, catalytic olefin technologies, ethylene and propylene

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[*]Corresponding author. Email address: t.ren@chem.uu.nl (T. Ren). Fax: +31.30.253.7601.

1 Introduction

Among the current IPPC installations, olefin production is the most energy consuming processes in the chemical industry, accounting for ca. 30% of the sector's total final energy use [1]. The core process for olefin production is steam cracking[1], which converts hydrocarbon feedstocks (naphtha, ethane, etc.) to olefins (ethylene, propylene, etc.) and other products, Steam cracking accounts for ca. 2-3 EJ primary energy use and ca. 180 millions tons of CO_2 emission worldwide (see Table 1). Reduction of this emission can help meet the emission targets set by Kyoto Protocol [2]. Energy cost is counted ca. 70% of production costs in typical ethane or naphtha based olefin plants [3, 4]. In addition, over 35% of the European crackers are over 25 years old. Therefore, energy management and re-investment are important considerations [5]. From both environmental and economic perspectives, it is therefore of interest to study energy losses in the existing processes as well as energy-saving potentials offered by recent improvements and alternative processes. Also, R&D priority setting and innovation policy studies may benefit from such characterization.

Many technical papers that describe alternative olefin processes with an emphasis on technical details on catalysis and engineering can be found in [6]. Interesting techno-economic studies for various ethylene processes have been done in the 1970s and 80s [7, 8]. A number of new olefin production technologies for short-term development were also reviewed by [9]. However, a thorough comparison of alternative olefin technologies and steam cracking that take into account energy allocation on byproducts and all feedstock production is still missing. It is interesting to study such olefin technologies, which might affect energy use in the next 20 to 30 years. Therefore, our research question is: what are possible technological developments in steam cracking and in alternative processes for the coming decade and how is their potential energy efficiency in comparison?

Our approach for energy analysis follows two stages. First, we try to understand the existing process and how energy is used. Then, we will make an inventory of new technologies and characterize them in terms of potential energy-efficiency improvement. This approach is similar to what has been used in [10]. This article is mostly based on data available in the public literature[2]. We limit ourselves to technologies that produce olefins from conventional (ethane, naphtha and propane) and heavy feedstock only. Also, due to its large share as a feedstock (Table 1), naphtha steam cracking is the main subject and ethane steam cracking is less discussed. Technologies involving other feedstocks, i.e. natural gas, biomass, coal, organic waste and CO_2 will not be discussed in this paper[3].

This paper first reviews background factors that affect energy use in olefin production in section 2. Section 3 gives a process description for naphtha steam cracking. Energy terms used in this article are defined in section 4. Section 5 presents

[1] It includes all production processes in a steam cracker, i.e. from pyrolysis to separation. See process description later.

[2] The major sources are of four categories: government reports (e.g. by EU Joint Research Center and US Department of Energy), journals (e.g. Oil & Gas, Hydrocarbon Processing, Catalyst Today and Fuel Processing Technology), conference proceedings (e.g. Ethylene Producers Conference) and publications by producers and licensors (e.g. Stone & Webster, UOP, Shell, etc.) Interviews and correspondences with producers and licensors made also a limited amount of contributions.

[3] We have completed an analysis of energy use, CO_2 emission and production cost for natural gas to olefins (UOP LLC MTO, ExxonMobil MTO and Lurgi MTP) and oxidative coupling of methane via ethane. Our conclusion shows that these new processes are far less efficient than the state-of-the-art steam cracking.

the results of the energy analysis. Under section 6, state-of-the-art and advanced naphtha cracking technologies are described. Section 7 discusses further on catalytic olefin technologies.

2 Background Factors

We will first discuss three background factors that are relevant for further analysis. They are: the role of steam cracking in the industrial sectors, market growth and feedstocks. First, steam cracking and its products, in particular olefins, have a backbone status for many industrial sectors. The worldwide demand and production of olefins are higher than any other chemicals [5]. Daily goods ranging from computer parts to pharmaceuticals are primarily derivatives of steam cracking products. In Western Europe, 95% of ethylene and 70-75% of propylene are produced through steam cracking [5]. The rest of propylene comes from refinery fluidized catalytic cracking (FCC) units (28%) and propane dehydrogenation or metathesis (2%) [5], which will be discussed later. In general, steam cracking plays a dominant role in olefin production.

Global ethylene production in the late 1990s has grown at a very high rate of 7-8% per year [11]. This is largely due to the strong demand growth in East Asia, especially by China, while the current market growth in the US and Europe was rather moderate [11]. In the last 2-3 years, the annual growth rate of the global olefin market slowed down to 3-4%. The propylene market is growing faster than the ethylene market by (1-3%). Recently, large capacities are being built or planned in the Middle East, but most of them produce ethylene from ethane, which is available at very competitive prices ($0.8-1.3/GJ in Middle East as opposed to $4/GJ in Asia) [11]. This might increase the global share of ethane relative to naphtha in the coming years (see Table 1).

There are two categories of feedstocks for the current olefin production: one derived from crude oil (such as naphtha, gas oil, propane, etc.) and another derived from natural gas (ethane, propane, etc.) (see Table 1). Their availability depends on the composition of crude oil and natural gas and their production volumes. Generally speaking in terms of weight, ca. 10% of oil refinery output is naphtha while 1-14% of natural gas is ethane and 80-90% is methane. Natural gas from the Middle East and Norway usually has higher ethane content than that from Russia. These regions together have 80-90% of the world's natural gas reserves [12].

3 Process Description of Naphtha Steam Cracking

Steam cracking typically refers to all processes inside the battery limits of a steam cracker. As Figure 1 shows, a steam cracker comprises the following three sections: pyrolysis (A), primary fractionation/compression (B) and product recovery/separation (C).

Pyrolysis section (A) This is the heart of a steam cracker. Naphtha first enters the convection section (where a series of heat exchangers are located) of a pyrolysis furnace and is preheated to 650 ^{o}C. Then, it is vaporized with superheated steam and is passed into long (12-25 meters), narrow (25-125 mm) tubes, which are made of chromium nickels alloys. Pyrolysis mainly takes place in the radiant section of the furnace where tubes are externally heated to 750-900 ^{o}C (up to 1100 ^{o}C) by fuel oil or gas fired burners [5]. Depending on the severity[1], naphtha is cracked into smaller

[1] High severity (characterized by residence time of less than 0.5 second and temperature up to 900-1100 ^{o}C) conditions increase ethylene yield (max. 5% increase) and lowers propylene yield. Low severity has the temperatures at lower than

molecules via free-radical mechanism in the absence of catalysts. The beta scission of the free radicals leads to the formation of light olefins in the gaseous state [14]. After leaving the furnace, the hot gas mixture is subsequently quenched in the transfer line exchangers (TLE) to 550-650 ^{o}C (or sometimes lower to 400 ^{o}C). TLE will then be followed by a series of heat exchangers and temperatures could drop down to 300 ^{o}C [13]. These heat-transfer activities avoid degradation by secondary reactions and at the same time generate high-pressure steam for driving compressors, etc. However, heat exchangers are prone to fouling[1] and therefore have to be shut down, both scheduled and unscheduled.

- *Primary fractionation/compression (B)* Primary fractionation applies to naphtha and gas oil feed only. In the primary fractionation section, gasoline and fuel oil streams (rich in aromatics) are condensed out and fractionated. While this liquid fraction is extracted, the gaseous fraction is de-superheated in the quench tower by a circulating oil or water stream. The gaseous fraction is then passed through four or five stages of gas compression (temperatures at ca. 15-100 ^{o}C), cooling and final cleanup to remove acid gases, carbon dioxide and water. Most of the dilution water steam are condensed, recovered and recycled. Fuel oil and BTX (aromatic gasoline which contains benzene, toluene and xylene.) are products from this section. A common problem with compression is fouling in the cracked gas compressors and after-coolers. The built up of polymers on the rotor and other internals results in energy losses as well as mechanical problems [16]. Wash oil and water are used to reduce fouling.
- *Product recovery and fractionation (C)* It is essentially a separation process through distillation, refrigeration and extraction. Equipment includes chilling trains (chilling and refrigeration) and fractionation towers (de-methanizer, de-ethanizer and the rest in Figure 1). De-methanization requires very low temperatures (e.g. –114 ^{o}C). C_2 (ethylene and ethane) separation often requires large distillation columns (splitters) with 120 to 180 trays and high reflux ratios [17]. Undesired acetylene will be removed through catalytic hydrogenation or extractive distillation. Similarly, in a C_3 splitter, C_3 (propane and propylene) are re-boiled with quench water at ca. 80 ^{o}C and separated. Ethylene and propylene refrigeration systems could be operated at low temperatures (within the range of –10 ^{o}C and -150 ^{o}C) for cooling and high pressure (200-450 psia) for compression [5, 18]. Ethane and propane are recycled as feedstock (not fully shown in Figure 1). Methane and hydrogen are separated at cryogenic temperatures. As fuel grade byproducts, they are often used as fuel gas in the pyrolysis process, but they can also be exported. Butadiene, other C_4 and aromatic gasoline are separated in the end. The total products yields from naphtha cracking differ depending on the paraffin and aromatic content of naphtha (full range, light, etc.) and severities (high, moderate and low).

Generally, steam cracking of ethane and other feedstocks also requires three sections that are similar to those in the case of naphtha cracking process [5]. However,

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800 ^{o}C and ca. 1 second residence time [13]. The degree of severity is described by the P/E ratio (propylene/ethylene). A P/E around 0.7 is low severity and any value below 0.5 is high severity. In Western Europe, the average severity for steam crackers is around 0.52 [5]. Severity is strongly restrained by metallurgy of the tubes and rapid coking tendency in the coils.

[1] Fouling is a complex science and is still an unresolved problem in the process industry. Simply explained, it is the degradation in heat transfer (or increase in the thermal resistance) due to a buildup of polymers or coke on the heat transfer surface. It also leads to higher hydraulic resistances that result in higher energy use [15].

the processes differ depending on feedstock properties and design arrangement, which often concern fractionation and separation sections [19]. For instance, ethane cracking requires slightly higher temperature in the furnace, higher capacity of C_2 splitter but less infrastructure facilities. Storage tanks or recovery equipment for propylene, butadiene and BTX aromatics are not needed, but an ethane vaporizer and super-heater are required.

An additional issue is about coking. Regular decoking is required in various parts of the pyrolysis section. Before decoking, the furnace first has to be shut down. Then, high pressure steam and air (sometimes hydrogen) are fed to the furnace while it is heated up to 880-900 ^{o}C, or even up to 1100 ^{o}C. Coke on the inner surfaces of the wall and tubes is either burned off, washed away with high pressure water or be removed mechanically. Decoking process can take 20-40 hours for a naphtha cracker [20]. Depending on the feedstocks, coil configuration and severity, decoking for steam cracking furnaces is required every 14-100 days in average [5]. Typically, a naphtha pyrolysis furnace is decoked every 15-40 days. Maximum cycle time is 60-100 days [5, 20]. Decoking is also required for quench towers, TLE and other sections.

4 Definitions

Energy indicators used in this article are defined as follows. The total energy use (per unit for a specific process) is our focus in this article. It does not exported energy (e.g. steam). The total energy use includes energy use in olefin processes and for additional imports (if applicable).

- Energy use in olefin process is the sum of fuel, steam and electricity in primary terms that are used for reactions (converting feedstock into olefins) and all the subsequent processes (e.g. compression and separation). This definition is referred to as "process energy use". Process energy use is usually defined as the energy use in an industrial process. Process energy use in the case of naphtha/ethane steam cracking is the sum of energy loss and thermodynamic theoretical energy requirement[1]. Process energy use is typically expressed in terms of specific energy consumption (SEC). These two terms are commonly used to measure the energy efficiency of ethane/naphtha steam crackers. In this article, the total energy use of steam cracking is the same as its process energy use or SEC, therefore, these three terms are used interchangeably *only* for steam cracking in this article.
- For several alternative, non-steam cracking processes (to be discussed later), however, energy use in olefin process is only part of the total energy use. Some of these processes import oxygen, hydrogen, electricity and/or steam. Primary energy uses in the production of these imports are also accounted as part of the total energy use. All of these energy uses are expressed in SEC as well.

[1] Energy loss represents the difference between the total energy input and total energy output. Thermodynamic theoretical energy requirement is the minimum energy input requirement for converting naphtha to end products. It is the difference between the total calorific value of products and the calorific value of naphtha at ambient temperatures. The former is larger than the latter because the overall naphtha-based steam cracking reactions are endothermic. Thermodynamic theoretical energy requirement is needed to produce products at certain yields from a given feedstock and it can neither be changed nor avoided. Therefore, process energy use can only decrease by reducing energy loss. However, since feedstock and product yields vary from process to process, thermodynamic theoretical energy requirements vary as well. In order to compare energy efficiencies across different processes, we believe process energy use for steam cracking (thermodynamic theoretical energy requirements and energy loss together) can be used as a basis for comparing energy efficiency in this article. Its calculations for steam cracking will be explained later

All energy figures are in terms of primary energy. Final energy figures for electricity and steam have been converted to primary energy using efficiency factors 40% and 85% respectively. Energy use in catalyst and equipment production is not included. Energy contents of products (or calorific values) are calculated based on their low heating value (LHVs) collected in [21].

The degree of energy efficiency is measured by the expression of SEC, GJ/t. This article uses several expressions of SEC, e.g. GJ/t feedstock, GJ/t ethylene or GJ/t high value chemicals (HVCs). In this paper, GJ/t ethylene means that all energy use is allocated to ethylene only and all other byproducts are hence produced “for free” in terms of energy use. This is not always the best indicator. For example, if ethane cracking is compared with naphtha cracking, it will not be fair to use GJ/t ethylene for comparison. Ethylene yield from ethane cracking is much higher than from naphtha cracking, but naphtha cracking also yields considerable amounts of other valuable byproducts (Table 2). For this reason, we believe GJ/t HVCs is a better indicator. HVCs include light olefins (ethylene, propylene and butadiene) and non-olefins. Non-olefins are aromatics and other C5+ in the case of steam cracking. While the mass of light olefins is fully taken into account, the mass of non-olefins is weighted with 50%[1]. The reason is that these non-olefin products are usually priced approximately half as much as light olefins[2] [22]. Our estimates for energy savings refer to savings on total energy use in terms of GJ/t HVCs.

This paper presents an exergy analysis for naphtha-based steam cracking. Exergy of an energy carrier refers to the maximum amount of work that can be extracted from an energy carrier. It is instructive to study exergy losses here because exergy analysis can locate where energy savings for a process are possible. Exergy loss in the naphtha-based steam cracking is considered equal to energy content of combusted fuels at ambient temperature.

All CO_2 emissions from the use of fuel-grade byproducts and external energy sources are counted. In this article, yield refers to final yield (after separation, recycling, etc.). It is defined as a percentage of desired products divided by hydrocarbon feedstock (oxygen not counted) on the mass basis, unless otherwise specified. Chemistry literature often uses per-pass yield on the mol basis. It will be noted where this definition is used in this paper.

5 Energy Analysis of naphtha/ethane steam cracking

Our energy analysis is aimed at searching for the areas for energy efficiency improvement. This section will first set a basis for further comparison of the total energy use in steam cracking, then it will show where energy and exergy are used in a typical naphtha steam cracker and finally it will discuss energy integration.

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[1] It is different from the definition of HVCs used in [5] where ethylene, propylene, butadiene, benzene and hydrogen are weighted with 100%. However, this does not lead to large differences in terms of SECs since the yield of non-olefins from steam cracking is small (e.g. aromatics yield max. 10%). Our definition of HVCs is useful to compare steam cracking with alternatives, e.g. catalytic cracking from which aromatics yield is high (15-30% see Table 5).

[2] Aromatics (pyrolysis gasoline) market prices are ca. $190/t in 2002-2003 [3, 22].

5.1 Typical Specific Energy Consumption

It is a difficult task to identify a SEC (GJ/t HVCs or GJ/t ethylene) that represents current process energy use by a typical existing naphtha crackers. Most data available are in SECs in terms of GJ/t ethylene and do not give further data on yields and methodologies. They are rather old, incomplete or within a very wide range. The world average SECs (excluding Japan and Korea[1]) in 1995 was ca. 30-36 GJ/t ethylene for naphtha crackers [23]. If we consider that an efficiency improvement rate is 1.7% per year for typical steam crackers in the past thirty years [5] and typical yields of HVCs in Table 2 are valid, then the SECs for a typical naphtha cracker should be approximately within the range of 26-31 GJ/t ethylene and 14-17 GJ/t HVCs.

Based on Table 2, calculations show that the thermodynamic theoretical energy requirement (see definition) for naphtha cracking is ca. 8 GJ/t ethylene or ca. 5 GJ/t HVCs. In the case of ethane steam cracking, this figure is ca. 5 GJ/t ethylene or ca. 5 GJ/t HVCs. Therefore, the SEC for a typical naphtha cracker is three times of the theoretical energy input needed to convert naphtha to final products. As earlier defined, SEC in the case of naphtha steam cracking is the sum of energy loss and thermodynamic theoretical energy requirement. So the energy loss in a typical naphtha-based steam cracking process is at least 17 GJ/t ethylene or 8 GJ/t HVCs. In this case, the energy loss is approximately equal to exergy loss since the energy discussed here is the energy content of fuel-grade byproducts combusted in the naphtha/ethane steam cracking.

5.2 Breakdown of SEC and Exergy Losses

Data for a breakdown of SEC and exergy losses found in literature are summarized in Table 3. For energy analysis, both thermodynamic theoretical energy requirement and energy loss are considered. Pyrolysis accounts for ca. 2/3 of the total SEC of naphtha crackers. The remaining third is consumed by compression and separation sections. The compression section (ca. 15% of the total energy use in naphtha cracking) uses slightly less energy than separation section (ca. 1/5 of the total energy use in naphtha cracking).

For exergy analysis, only exergy loss (17 GJ/t ethylene) due to fuel combustion is considered. With respect to exergy in pyrolysis section of naphtha crackers, ca. 75% of the total exergy losses are estimated to occur in the naphtha pyrolysis section. Fuel combustion is predictably the main cause. These large exergy losses can be illustrated by the high temperature drops across heat exchangers, which are mostly in the range of 100-300 ^oC and even near 500 ^oC in the TLEs. Throughout the whole pyrolysis process, the total temperature drop is more than 1100 ^oC and the total pressure drop is over seven mpa [25].

With respect to exergy use in the rest of sections in a naphtha cracker, the large losses occur in propylene refrigeration, de-ethanization/C_2 splitter and compression. Exergy losses that occur in the compression and separation sections mainly are caused by the production of electricity used in refrigeration and compression. All these exergy losses are not surprising if the conditions in separation and compression sections are considered. As the process description has indicated, most of the conditions for

[1] The SECs of naphtha steam crackers in Japan and Korea in 1995 are exceptionally low, namely ca. 25 GJ/t ethylene [23]. About 40% of steam crackers in Europe have SECs at ca. 31-35 GJ/t ethylene [5]. Naphtha and gas oil steam crackers in the US have SECs at ca. 32 GJ/t [24].

refrigeration are very cryogenic: low temperatures (as low as -150 °C) and high pressure (up to 450 psia).

Ethane cracking has a similar distribution of energy consumption. However, an important difference from naphtha cracking is that the contribution of SEC in the pyrolysis section of ethane cracking (ca.1/2) is less by percentage than that in the case of naphtha cracking (ca. 2/3). In turn, the contribution of SEC in compression and separation sections is slightly higher in the case of ethane cracking than that in the case of naphtha cracking. The chiller that condenses and separates ethylene and ethane uses up to ca. 21% of the total energy consumption [26]. As our process description mentioned, ethylene and ethane have similar boiling points, which explains why this separation task is very energy consuming.

As mentioned in the process description of steam cracking, additional energy used in decoking/defouling, shutdowns/restarts and related maintenance for various sections of a steam cracker could consume up to ca. 1-2% of the total energy use in the existing processes [27]. This additional energy use in decoking and defouling is usually not counted as part of SEC in steam cracking. Shutdowns also directly lead to large monetary losses. Therefore, it is not surprising to hear that the greatest challenge for steam-cracker engineers today is to improve the on-stream factors (intervals between shutdowns) by reducing coke formation and to extend furnace life between tube replacements [28].

5.3 Energy Integration

In the case of naphtha cracking, process energy used in the pyrolysis section is provided through combustion of fuel gases, which are fuel-grade byproducts in significant volumes. These byproducts, together with flue gases (not fuel gases) and waste heat, can meet ca. 95% of process energy demand in naphtha steam crackers [24]. These fuel-grade byproducts amount to ca. 20-25% of the energy content of naphtha (ca. 10-12 GJ out of LHV 44 GJ/t naphtha). Energy needed for compression and separation sections is provided by steam, which can almost all be produced from heat exchangers, or so called Transfer Line Exchangers (TLEs). Typically, steam is in balance, which means that there is no net steam import or export. A small amount of electricity is provided from external sources [29]. Electricity is used primarily for running cooling water, quench oil pumps and sometimes methane compressors [24]. It amounts to ca. 1 GJ/t ethylene [24]. Backflows to refinery and energy export together can be up to ca. 9-10 GJ/t ethylene for naphtha cracking [24]. In contrast to naphtha cracking, ethane cracking is not self sufficient in terms of energy and therefore requires energy import (15% of the total SEC through various energy carriers) [30].

6 Latest Developments of Naphtha Steam Cracking

In search for alternatives, we draw a family portrait of olefin technologies sorted by feedstocks (Figure 2). We have chosen a number of the latest technologies based on the following criteria: using conventional or heavy feedstocks, undergoing active research and being highly visible in recent publications, recently emerging or being commercialized and possibly having significant impacts on energy use. In the following sections, these technologies will be discussed in two categories: (6.1) state-of-the-art naphtha cracking processes (Table 4); (6.2) advanced technologies in specific sections of naphtha steam cracking.

6.1 State-of-the-Art Naphtha Steam Cracking[1]

Table 4 is an attempt to summarize state-of-the-art technologies for naphtha steam cracking, which is sorted by licensors. These technologies are offered as the most standard, widely accepted processes to olefin producers if they want to build a new olefin plant today. Table 4 contains only limited, public available information. For the separation section, only information on the de-methanization for each licensor was available. Regarding pyrolysis furnaces, most technologies focus on optimization design of furnace coils, which are located in the radiant section where cracking occurs (see process description in section 4). The goal is to improve heat transfer, raise severity, minimize coking and maximize olefin yields. As Table 4 shows, small, double coils and double radiant cells seem to be common features. With respect to improvements in separation processes, front-end de-methanization reduces refrigeration needs and therefore energy demand. For example, ABB Lummus claims a 75% cut in refrigeration needs [31]. However, traditional energy-consuming refrigeration and distillation as the main separation method remain unchanged. Further, no significant changes in the subsequent sections (compression and C_2, C_3 and C_4 separation) are reported as part of state-of-the-art naphtha steam cracking technologies.

These processes in Table 4 could reach SECs in the range of ca. 18-25.2 GJ/t ethylene, which is equivalent to a saving of ca. 20% on current average SEC (26-31 GJ/t ethylene). Gas turbine mentioned in Table 4 is not being commonly offered by every licensor. It will be discussed again in the next section. Without considering gas turbine, we consider the average SECs for state-of-the-art naphtha steam cracking is ca. 20-25 GJ/t ethylene and 11-14 GJ/t HVCs. HVCs yields used in the calculation are based on data reported by ABB Lummus[2]. The SEC figures (11-14 GJ/HVCs) by state-of-the-art naphtha cracking technologies are still far more than the absolute thermodynamic theoretical energy requirement for naphtha to olefin conversion mentioned earlier (5 GJ/HVCs).

In addition to Table 4, we observed a trend that the sizes of state-of-the-art crackers are increasing. While the current average steam cracker is around 450,000-500,000 tons ethylene per year [5], new naphtha crackers can produce over one million tons of ethylene annually (tpa). Technip built a plant with ethylene capacity of over 1.2 million tpa in Iran [32]. KBR (Kellogg Brown & Root) claims that they are able to build a two-million tpa ethylene plant [33]. The same trend goes with ethane crackers as well. Stone & Webster built an ethane cracker for NOVA in Canada with ethylene capacity of 1.27 million tpa. Technip claims the SEC of their mega cracker is 20 GJ/t ethylene as opposed to the average 30 GJ/t ethylene[3] [32].

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[1] State-of-the-art is technologies that would be used if a new plant is to be built nowadays. For example, those process introduced in the "petrochemical processes 2003" in [31], which are commonly offered by licensors.

[2] ABB Lummus' steam cracking technology is said to be used by over 40% of the world's olefin plants [31].

[3] Technip also claims that their mega crackers have lower product losses (0.25% in comparison with the average 1%), lower CO_2 emission (half of the average 1.6 t/t ethylene in Table 2) and lower operational cost advantages because of economy of scale [32]. Technip also claims that the maximum capacity may have been reached mainly due to the limits of compressors.

6.2 Advanced Naphtha Steam Cracking Technologies

Advanced technologies in specific sections in a naphtha cracker are not being offered by major licensors as part of standard commercialized processes. In fact, some of them are commercially available, but due to high costs, most of them are not yet widely implemented. Others are new and their technical and economic feasibility have yet to be proven.

With respect to the pyrolysis section, there are a few significant innovations and all of them are aiming at improving heat transfer and raising severity. There are circulating solids/particles (such as sand, coke and other carriers), circulating beds [34], selective radiant coils (which allows better control of P/E ratio by adjusting combustion gas) [35], ceramic coated tubes/coils and other advanced furnace materials [28, 36]. Here we only discuss *Advanced furnace materials*. Reducing coking can greatly improve heat transfer in furnaces. Traditionally, coking can be partially inhibited by a sulfur-compound based chemical treatment of inner walls of tubes/coils. Advanced tubes and coils in various shapes (e.g. cast-fins) are coated with glass, ceramics (aqueous salt of IA/IIA metals, silicon and phosphorus compounds) and they do not need chemical treatment [28, 37, 38]. Coating can also have catalytic effects for olefins selectivity [39]. Also, coating could allow higher severity and thereby enhance ethylene yields. Sintered silicon carbide (SiC) ceramics, for instance, offer maximum skin temperature up to 1400 ^{o}C , high conductivity and low surface catalytic activity [40-42]. Conventional pyrolysis tubes made of Cr-Ni alloys allows the maximum skin temperature only up to 1100 ^{o}C [41]. It is estimated that these advanced materials could lead to up to ca. 10% savings on current average SEC, or ca. 2-3 GJ/t ethylene[1].

An additional new technology is *gas turbine integration*. Gas turbine integration results in the export of both steam and electricity. Also, it produces hot combustion gas for feedstock heating in a pyrolysis furnace. It can possibly save 13% (ca. 3 GJ/t ethylene) on the SEC of state-of-the-art steam cracking technologies [43] [44]. If both advanced furnace materials and gas turbine are applied, ca. 20% energy saving (ca. 4 GJ/t ethylene) on the SEC of state-of-the-art naphtha steam cracking is possible.

With respect to compression and separation section, possible improvements are: Vacuum Swing Adsorption Process (VSA), mechanical vapor recompression (MVR), advanced distillation columns, membrane and combined refrigeration systems. VSA uses solid sorbents for selective light olefin adsorption (such as ethylene and propylene) over paraffin (such as ethane and propane). MVR could be used in a conventional propane/propylene splitter. It can lead to ca. 5% (ca. 1 GJ/t ethylene) saving on the SEC of state-of-the-art steam cracking [45].

Advanced distillation column technology has been studied since 1930s as thermally coupled column. One type of such columns is “divided-wall” distillation columns for butadiene extraction. It could save ca. 16% on the SEC in the conventional butadiene distillation section [46]. Another type of such advanced distillation column is Heat Integrated Distillation Column (HIDiC). Two variations of HIDiC developed in the Netherlands are called *Plate Fin* and *Concentric* [47]. These advanced columns improve heat transfer by building heat exchangers between stripping and rectifying sections. They can be applied in ethylene/ethane (E/E) splitter and propylene/propane (P/P) splitter. It is generally estimated that HIDiC saves ca. 60 to 90% energy (or 0.1-0.3 GJ/t ethylene) on the SEC of a conventional P/P distillation column, which is known for poor

[1] This estimate is based on personal communications quoted in [35].

energy efficiency (ca. 20-30%) [47-49]. HIDiC is even possible to save ca. 50% (ca. 0.15 GJ/t ethylene) on the SEC in modern distillation columns with heat pumps [47].

Membrane is another long-known technology, but it is rarely applied in steam cracking. Membrane materials are often made of polymer (e.g. polypropylene) or inorganic materials. Membranes can be possibly applied in separation of olefin/paraffin (C_2/C_3), gases (hydrogen recovery[1], acids, etc.) and coke/water (water purification) [51]. Membranes could combine high selectivity with a high permeability. With regards to the membrane application in the C_2 and C_3 separation alone, ca. 8% (1.5 GJ/t ethylene) savings on process energy is expected [52]. However, membrane separation is widely believed as an immature technology because it is unable to withstand severe operating conditions and needs regular replacement (due to erosion, etc.). Therefore, membrane is not yet licensed by any steam cracking licensors.

Energy integration of a steam cracker with another industrial process can also possibly save energy. *Combined refrigeration* synchronizes the cryogenic natural gas liquid plant, natural gas liquid fractionation and ethylene plants into a single unit [53]. It is claimed that the total refrigeration requirement by an ethylene plant is reduced by 60-80%, or ca. 1 GJ/t ethylene can be saved [53].

Since some of the technologies mentioned above could be applied in the same process (e.g. HIDiC columns and membrane for C_2/C_3 separation) and most of them are not yet mature, it is not possible to simply add up all the energy savings together. Considering the distribution of SEC described in Table 3, we roughly estimate that advanced steam cracking technologies altogether could lead to up to ca. 15% of energy savings (ca. 3 GJ/t ethylene) on the SEC of state-of-the-art steam cracking.

7 Catalytic and other Alternative Technologies

7.1 Energy Use

An alternative to conventional steam cracking comprises catalytic and other alternative olefin technologies, which can process conventional or heavy feedstock. Table 5 is a list of these technologies in the order of feedstock weight from light (left) to heavy (right). Note that technologies in Table 5 only differ from the pyrolysis furnace of a steam cracker. The rest, including compression and separation sections, are assumed to be similar to those of state-of-the-art steam cracking. The first three technologies use gas feedstocks. *Gas stream* technologies use gases as heat carriers to provide enthalpy needed for pyrolysis [54, 55]. *Shockwave* technology uses steam at supersonic speed as heat carrier and the process is volumetric, not limited by heat transfer through metal walls and tubes as for the conventional steam cracking [54]. It uses ca. 45% (primary energy use for steam production included) less than the SEC of the state-of-the-art steam cracking [56]. Olefin producers are very concerned about the overall system complexity that result from large requirement of steam (ca. 5-10 times the steam requirement by conventional steam cracking) and subsequent energy recovery from waste steam [54]. R&D on shockwave technology was stopped in 1998.

There are two oxidative dehydrogenation processes, both for processing gas feedstocks. Both processes require oxygen with high purity (ca. 90%). *Ethane oxidative*

[1] Hydrogen recovery may have been among the first wide-scale commercial application of membrane [50].

dehydrogenation has ca. 35% potential saving[1] (primary energy use in oxygen production included) on the SEC by state-of-the-art ethane cracking [57]. Another process is *propane oxidative dehydrogenation*. This process produces little ethylene. Ethylene yield from steam cracking of propane is up to 45% and propylene yield is 12% [30]. Propane oxidative dehydrogenation has potential to lead to ca. 45% (primary energy use in oxygen production included) savings on the SEC by conventional propane steam cracking, which is 15-18 GJ/t HVCs.

The rest of technologies in Table 5 use naphtha or heavy feedstocks. SEC by *catalytic cracking of naphtha* is estimated to be within 10-11 GJ/t HVCs. This is also ca. 10-20% less than the SEC by the state-of-the-art naphtha cracking (11-14 GJ/t HVCs). Some of these processes, developed by LG (a major Korea chemical company) and AIST (a Japanese research institute), are reported to be commercialized soon.

Hydro-pyrolysis (non-catalytic) could save ca. 9% (primary energy use in hydrogen-methane fraction included) less than the SEC by the state-of-the-art naphtha cracking. The reasons for such energy savings include several factors: higher yields, lower temperature in the furnace (heat coefficient of hydrogen higher than methane or fuel oil), low coking and less steam requirement [59].

Byproduct upgrading technologies produce olefins by processing the byproducts (ranging from C_4 to C_9) from conventional steam cracking or from refinery [22]. As an add-on process to naphtha cracking, byproduct upgrading technologies can raise the total propylene yield of naphtha cracking from the average 15% to 30%. This process has a potential saving of ca. 7-10% less than the SEC by the state-of-the-art naphtha cracking.

Using heavy feedstocks, such as crude oil, the *catalytic pyrolysis process (CPP)* saves ca. 12% on the SEC of the state-of-the-art naphtha cracking. Because CPP feedstock can be crude oil and other heavy feedstock, energy use in naphtha production is avoided, which is about ca. 2-3 GJ/t naphtha [49] If this is taken into account in the comparison with naphtha steam cracking, the energy savings by CPP would be ca. 20%. Another important reason for energy saving is the mild reaction conditions in CPP. Its reaction temperatures are around 650-750 ^{o}C, which is 150-350 ^{o}C lower than steam cracking [60, 61].

The energy savings estimated here are due to improvement of energy efficiency in the pyrolysis section. If the advanced separation technologies (mentioned under 6.2) are also applied, then the energy savings by catalytic olefin technologies on the SEC by state-of-the-art naphtha cracking could be up to ca. 40%. Among the alternative olefin technologies discussed, gas stream and hydropyrolysis (non-catalytic) have not been actively pursued by the industry in recent years. However, catalytic olefin technologies are under intensive R&D, especially in China and Japan.

[1] However, if the CO_2 emission from oxygen usage is included, the total CO_2 emission by ethane oxidative dehydrogenation is 0.31 ton CO_2 per ton ethylene produced. This is 15% higher than that from ethane cracking. Ethane cracking emits less due to combustion of hydrogen although it uses more energy per ton of ethylene than ethane oxidative dehydrogenation [57]. Oxygen production (if using electricity) requires primary energy ca. 3-4 GJ/t oxygen [58]. Its emission factor is assumed as 60 kg CO_2/GJ. In the future, this CO_2 emission factor could be reduced by membrane or other efficient oxygen production processes.

7.2 Reactors and Catalysts

It is interesting to discuss further about possibilities for energy saving by these catalytic olefin technologies just mentioned[1]. The emergence of catalytic olefin technologies is in line with the recent discussion on energy saving through process intensification[2]. This is reflected by the reactors and catalysts used in catalytic olefin technologies. The reactors of new catalytic technologies[3] in Table 5 often share similar reactor design with conventional FCC reactors used in refineries (fixed or fluidized bed catalytic cracking reactors). China's SINOPEC has named its catalytic olefin technologies (e.g. CPP) as "FCC family techniques" [64]. FCC reactors are smaller than pyrolysis furnaces. Also, moving beds and catalysts used in FCC enable intensive contact between catalysts, reactors and feedstocks (by maximizing contact surface) and consequently, such intensity leads to efficient heat transfer. Unsurprisingly, FCC reactors[4] are known for using less energy in terms of SEC/t feedstock (SEC ca. 2-3 GJ/t feedstock) [49] than steam cracking furnaces (SEC ca. 5-9 GJ/t ethane or naphtha) [49]. Because catalytic reactors usually operate under lower temperatures than those for steam cracking, it is possible to use recovered waste heat (combined with fuel combustion) as sources of process energy [25].

The use of catalysts is commonly known for energy saving. Zeolite FCC catalysts adopted by US refinery in 1977 have helped save 200 million barrels of crude oil (30 million tons) in the US alone [66]. Similarly, many of catalytic technologies mentioned in Table 5 use zeolite (other also use metal oxides) catalysts[5]. Figure 3 illustrates that catalytic olefin technologies can save activation energy use in conventional steam cracking. There are three reasons for such energy saving.

- First, these catalysts provide an alternative route to steam cracking with the use of lower activation energy for C-C bonds rupture. In the case of CPP, this means the cracking can be carried out at moderate temperature and pressure in comparison with steam cracking [14]. Also, most of the catalysts cannot withstand extremely high temperatures and pressures as in steam cracking (up to 1,100 °C and 75 mpa). Consequently, the temperatures for the new catalytic naphtha cracking processes are 150-250 °C lower than those for steam crackers (Table 5).

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[1] This is not to say all catalytic pyrolysis technologies for olefin production save energy in comparison with the state-of-the-art steam cracking. We limit our discussions only on those listed in Table 5 that are believed to have energy saving potentials.

[2] The term basically means that better heat and mass transfer in smaller and faster reaction systems with less steps lead to higher conversion, better efficiency, less waste and safer control systems [62].

[3] Catalytic olefin technologies, there are basically two categories: acidic catalytic cracking and thermal catalytic pyrolysis [63]. Acidic cracking is associated with zeolite catalysts, FCC-like riser/bed reactors and heavy feedstocks. This technology is being developed by Sinopec/Stone & Webster (in commercial test), ABB Lummus, KRICT, LG, Asahi and AIST. Thermal catalytic pyrolysis is associated with various kinds of metal oxide catalysts and naphtha. The reactors are often similar to tubular furnaces used in steam cracking, but FCC-like reactors are also being tested. This technology is being developed by VNIIOS (in commercial test), Toyo, IIT, Stone & Webster, Idemitsu, KRICT and LG.

[4] FCC reactors operate under low temperature: ca. 450-600 °C, which is 200-400 °C less than steam cracking [65]. However, it is commonly known that FCC ethylene yield usually only is 1-2% and propylene yield is 5% while naphtha yield is over 50% and cycle oil yield is 20% [49].

[5] Zeolite catalysts are complex alumino-silicates and are large lattices of aluminum, silicon and oxygen atoms. In the case of FCC, zeolite catalysts lead to formation of carbonium ions. These ions then reorganize and lead to various FCC products. In the case of catalytic olefin technologies, the combined use of zeolite and other catalysts lead to formation of both carbonium-ions and free-radicals [64, 67]. They are then reorganized and eventually lead to light olefins, aromatics and other products [14].

- Second, catalysts improve selectivity to desired products, such as propylene [68]. Even if the same operating conditions as those of steam cracking are applied for catalytic cracking, the total olefin yield by LG's catalytic pyrolysis technology is still enhanced by at least 15% [68].
- Third, coke formed during the cracking process is constantly removed by catalysts that are in turn de-coked through catalyst regeneration (or catalyst decoking). As said earlier, coke lowers energy efficiency by hindering heat transfer.

Earlier attempts to catalytically convert heavy hydrocarbons to light olefins often showed that the use of catalysts is often problematic because of thermodynamic equilibrium limitations, coking, low yields of olefins and high yield of low-value byproducts[1] [64, 69]. The new catalytic technologies in Table 5 have made some progresses in solving these problems, but continuous improvement is still needed.

- First, regarding the problem with the equilibrium limitation, oxygen is used to drive the reaction toward the desired direction and to take advantage of heat generated by oxidation. As a result, excessive heating and high pressure are not required and thereby energy efficiency is improved [65]. At the same time, oxygen can also burn off coke on the catalysts. Also, reactors using inorganic catalytic membranes could also separate oxygen, ethane/naphtha, hydrogen and other products (reducing undesired reactions) and improve the conversion of equilibrium limited reaction [70, 71].
- Second, older metal oxide catalysts were prone to coking and quickly deactivate. Therefore, high temperatures and short residence time were required to hinder coking. High temperatures (800 ^{o}C or above) and extremely short residence time (in milliseconds), however, are often very harsh on catalysts and result in quick deactivation of catalysts and short lifetime. Recently, new zeolites catalysts (e.g. metal, silica and hybrid) have shown to have less coking and to be more effective under higher temperatures [61, 72]. One recent patent on catalytic olefin technologies claims that new catalysts can reduce CO_2 and methane contents in the air stream from catalyst regeneration by 90% and 50% respectively in comparison with the CO_2 and methane content in the air stream from steam cracking [65].
- Third, older catalysts often show strong selectivity to aromatics and heavy hydrocarbons instead of light olefins. New catalysts, such as Ga-P zeolite, suppress aromatization and provide relatively high yield of ethylene and propylene [73].

7.3 Short and Long-Term Prospects

According to major worldwide licensors and research institutions we have contacted through 2002 to 2004, currently none of these catalytic olefin technologies listed in Table 5 are fully mature and economically competitive in comparison with state-of-the-art

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[1] Coke can be significant even at high reaction temperature. It can currently only be burned through catalyst generation and is very problematic if it remains in the final products. Catalytic olefin technologies often yield large amount of methane and hydrogen, which need much energy at cryogenic conditions to be separated. Other low-value byproducts, such as aromatic-rich gasoline is difficult to be used due to instability caused by olefins, but additional processing will lead to high costs [64].

steam cracking technologies. Nevertheless, it is of our interest to discuss the short and long-term prospects of catalytic olefin technologies.

In the short term, catalytic olefin technologies appear to be driven by two economic factors: strong demand for propylene and low cost feedstock [74, 75].

- First, propylene demand is an economic factor that is often discussed. The three catalytic technologies in the middle of Table 5 are devoted to produce propylene and are sometimes referred to as "propylene on purpose" [11]. For the same reason, conventional FCC used in refineries (cracking heavy feedstocks) also becomes attractive for R&D since it yields considerable amount of propylene (up to wt. 17%) and is likely to supplement propylene supply unfulfilled by steam cracking [74, 76].
- The second economic factor is feedstock. Heavy feedstocks (heavier than naphtha), such as gas oil and heavy residues indicated in the center of Table 5, are cheaper than naphtha and ethane and they can also yield multiple high value byproducts [65]. Such feedstocks are attracting much attention in the US, Europe and Asia. Cracking heavy feedstock can enhance competitiveness compared to ethane cracking in the Middle East. Therefore, the overall economics for upgrading heavy feedstock to high value olefin products (in particular propylene) looks quite attractive. Besides unsolved technical problems, whether the production volume by using these new technologies is able to increase further will be decided partially by propylene market pull and partially by cost competition between conventional and heavy feedstocks.

In the long term, more and more R&D can be expected to be devoted to catalytic olefin technologies because of their potentials in energy saving as well as upgrading low-value heavy feedstocks. Catalysis has brought tremendous progresses to many fields in the chemical industry, but unfortunately it has not been capitalized in light olefin production. Steam cracking essentially is a non-catalytic and non-selective process. Catalysts have never been widely used in the pyrolysis section in steam cracking to optimize energy efficiency. The application of catalysts in cracking naphtha and ethane has only become attractive since the beginning of 1990s. Beside those institutions in Korea, Japan and China (mentioned under Table 5), major licensors (e.g. Stone & Webster and ABB Lummus) and olefin producers (e.g. ExxonMobil and BP) are also filing patents on catalytic olefin technologies. Recently, catalytic processes developed by AIST, Sinopec/Stone & Webster and VNIIOS are said to be already under commercial tests [63]. Adoption of FCC-like catalytic olefin technologies has been expected since more than ten years ago [25]. Whether these new processes can replace steam cracking will depend on how well they mature both technically and economically in the next 20 to 30 years.

In a word, after reviewing alternative technologies in Table 5, we conclude that there is a strong rising interest in applying special reactors and catalysts to control yield and thereby to improve energy efficiency, but the future development of catalytic olefin technologies will be strongly affected by maturity of catalytic technologies, market pull and feedstock cost competition.

8 Conclusion

Issues concerning the reduction of energy use, costs and emissions by olefins production initiated this analysis of olefin technologies. The findings from our energy analysis indicated the most important sections in terms of the energy use, e.g. pyrolysis section alone accounts for ca. 65% of total energy use and ca. 75% of the total exergy losses. This paper then discusses the latest olefin technologies that still use conventional feedstocks. An overview of state-of-the-art naphtha cracking technologies offered by licensors shows that ca. 20% savings on the current average energy use are possible. Advanced naphtha steam cracking technologies in the pyrolysis section (e.g. advanced coil and furnace materials) may together lead to up to ca. 20% savings on the energy use by state-of-the-art technologies. Improvements in the compression and separation sections may together lead to up to ca. 15% savings on the energy use by state-of-the-art technologies. Alternative olefin technologies apply special reactors, catalysts or additional materials (oxygen, hydrogen, etc.) to crack conventional and heavy feedstocks. In particular, catalytic olefin technologies can lead to higher yields of valuable chemicals (e.g. propylene) under lower reaction temperatures. Due to energy efficiency improvement in the pyrolysis section, catalytic naphtha cracking could possibly save up to ca. 20% on the energy use by the state-of-the-art naphtha steam cracking is possible.

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Figure 1 Typical Flow Diagram for a Naphtha Steam Cracker[1]

[1] Figure was drawn based on [5, 77].

Figure 2 Family Portrait of Olefin Technologies: Current and Future

BATH: Bio acid acetone to hydrocarbons (such as olefins) [6];

CC: Catalytic Cracking or catalytic pyrolysis;

DCC: Deep catalytic cracking, etc. (see Table 5);

DH: Dehydration process (such as methanol to olefins, methanol to propylene and ethanol dehydration); [13, 78];

FM: Fermentation [79, 80]:

FP: Flash pyrolysis, sometimes in the presence of methane [80];

FT: Fischer Tropsch synthesis (using syn-gas CO and H2 mixture to synthesize methanol or other products) [6];
GAS: Gasification; LIQ: after gasification, then liquefaction [6, 79];

GS: Gas stream reactor technologies, such as shockwave reactors (Table 5)

HG: Hydrogenation [6, 79];

HP: Hydro-pyrolysis (see Table 5);

HTUL: Hydro-Thermal Upgrading Liquefaction which produces naphtha from biomass feedstock [6, 79];

OC: Oxidative coupling via ethane [6];

OD: Oxidative dehydrogenation [6];

OM: Olefin metathesis, e.g. ABB-Lummus Olefin Conversion Technology, IFP-CPC meta-4 [81];

OU: Olefins Upgrading (conversion of C4- C10) to light olefins, such as Superflex [82], Propylur [83] and Olefins Cracking [22].

PD: Propane dehydrogenation [84, 85];

RCY: Re-CYcling pyrolysis using organic waste, such as discarded plastics, used rubber, etc.[6, 79];

REC: Recovery of refinery off gases, which contains ethylene, propylene, etc.. [79];

REF: Oil refinery process. Distillation produces naphtha and heavy oil. Catalytic cracking produces off gases. Cryogenic and absorption produces ethane and LPG;

SC: Steam Cracking (conventional);

SEP: Gas Separation Process which produces methane, ethane and propane;

SR: Steam Reforming of natural gas, a process which in this case produces methanol

Figure 3 Simplified Energy Profile of Conventional Steam Cracking and Catalytic Olefin Technologies

Table 1 Estimated Global Energy Use and CO_2 Emission by Current Olefin Production[a]

	World	US	Europe (including new EU member states and FSU)
Total feedstock (Million tons)[b]	300	85	90
Breakdown of Feedstock (wt. %)	naphtha 55, ethane 30, LPG[c] 10, gas oil 5	ethane 55, naphtha 23, propane15, gas oil 5	naphtha 75, LPG 10, gas oil 9, ethane 5
Ethylene capacity (Million tons)	110-113	28-30	30-32 (23-24 by Western Europe)
Propylene capacity (Million tons)	53-55	16-17	17-18
Total energy use (fuel combustion and utilities included) (EJ)[d]	2-3	0.5-0.6	0.7-0.8
Total CO_2 emission[e] (fuel combustion, decoking and utilities included) (Million tons)	180-200	43-45	53-55

[a] We estimated energy use on the basis of current production level. The annual growth rate of olefin production for 2003-2004 is assumed at 3.5% [11].

[b] Feedstock, ethylene and propylene production data are based on [86, 87]; US figures come from [24].

[c] LPG is a mixture of ethane, ethylene, propane, propylene, butane and butylenes.

[d] Since the world production between 1994 and 2004 went up from 50 to over 110 million tons of ethylene per year, we estimated that global energy used in olefin production has more than doubled from 1EJ in 1994 [88]. US. Department of Energy put the global process energy used in ethylene production as 2.6 EJ when the global ethylene production is 93 million tons in 2000 [89].

[e] CO_2 emission and process energy use are based on [5, 30]. Decoking is based on [36]. US figures are lower than those of Europe due the fact that heavy feedstock uses more energy use in total.

Table 2 Overview of Two Currently Most Used Conventional Feedstocks in Olefins Production

	Ethane	Naphtha
SEC (GJ/t ethylene)[a]	17-21 (typical) 15-25 (maximum)	26-31 (typical) and 20-40 (maximum)
SEC (GJ/t HVCs)	16-19 (typical)	14-17 (typical)
CO_2 emission (t CO_2/t ethylene)[b]	1.0-1.2 (typical)	1.8-2.0 (typical)
CO_2 emission (t CO_2/t HVCs)	1.0-1.2	1.6-1.8
Ethylene yield (wt. %)[c]	80-84%	29-34% (30% typical)
Propylene yield (wt. %)	1-1.6%	13-16%
Butadiene yield (wt. %)	1-1.4%	4-5%
Aromatics and C4+ yield (wt. %)	2-3%	10-16%
HVCs yield (wt. %)	82% (typical)	55% (typical)
Methane yield (not counted as HVCs) (wt. %)	4.2%	13-14%
Hydrogen yield (not counted as HVCs) (wt. %)	4.3%	1%
Backflows to refinery (wt. %)	0%	9-10%
Losses (due to fouling, coking, etc.) (wt. %)	1-2%	1-2%

[a] Energy use is based on [24, 30]. SEC here only refers to process energy use in pyrolysis and separation.

[b] Emission is calculated based on [30, 90]. Emission is a result of fuel combustion and utilities, both of which use fossil fuel. Ethane cracking results higher hydrogen and ethylene content, therefore less CO_2 emission per ton of ethylene, than naphtha cracking does.

[c] Yield data is based on [30, 31]. Yields are on the mass basis and are all final yields.

Table 3 Breakdown of Specific Energy Consumption (SEC) and Exergy Losses in Steam Cracking Process

		Ethane	Naphtha				
		SEC[a]	SEC		Exergy loss		
		[26]	[29]		Our estimation[b]	[25]	[91] [18]
Pyrolysis	Heat of reaction	23%[c]	65%	Fuel combustion and heat transfer to the furnace	75% (or 15 GJ/t ethylene)	73%	N/A
	Steam, heating & losses	24%		Heat exchange with steam, TLEs and heat loss to flue gas		27%	
Fractionation and Compression		22%[d]	15%[e]	Fractionation[f] and Compression	25% (2 GJ/t ethylene in compression and the rest of separation processes)	N/A	19%
Separation		31%	20%	De-methanization			12%
				De-ethanizer and C_2 splitter			23%
				C_3 splitter			2%
				De-propanization/ De-butanization			10%
				Ethylene refrigeration			5%
				Propylene refrigeration			30%
Total process energy use		100%	100%	Total exergy losses	100% or 17 GJ/t ethylene	100% (only pyrolysis section)	100% (only compression and separation)

[a] All energy figures in the table is in primary energy terms. Generally speaking, the contribution of electricity is very small ca. 1 GJ/t ethylene [24]. Steam is produced internally and is in balance. Almost all process energy (including steam) originates from combustion of fuel-grade byproducts and extra fuel (only in case of ethane cracking). The distribution of byproduct/fuel energy contents is represented by the percentages in the table.
[b] Our estimate on the pyrolysis section is based on [25]. Our estimate on the compression and separation sections is based on [18, 91].
[c] Another figure for heat of reaction given in [8] is 21%. Energy use for "heat of reaction" refers to the energy used to convert feedstocks into desired products.
[d] Another figure for compression given in [8] is 16%.
[e] Another figure for compression given in [8] is 13%.
[f] Data on the exergy loss in fractionation and quench towers is not found. We roughly estimated the exergy loss here is below 0.2 GJ/t ethylene.

Table 4 State-of-the-Art Naphtha Steam cracking Technologies sorted by Licensors[a]

Licensors	Technip-Coflexip[b]	ABB Lummus[c]	Linde AG[d]	Stone & Webster[e]	Kellogg & Brown Root[f]
Coil related furnace features	Radiant coils pretreated to reduce coking with a sulfur-silica mixture	Double pass radiant coil design; online decoking reduces emissions	Twin-radiant-cell design (single split) is 13m (shorter than the average length 25m)	Twin-radiant-cell design and quadra-cracking	Coil design (straight, small diameter), low reaction time; very high severity
De-methanizer separation features	Double de-methanizing stripping system	De-methanizer with low refrigeration demand	Front-end de-methanizer and hydrogenation	De-methanization simultaneous mass transfer and heat transfer	Absorption-based demethanization system with front-end design
Gas Turbine	N/a	Ca. 3 GJ/t ethylene saved	N/a	Offered but no data	N/a
Ethylene Yield (wt. %)	35%	34.4%	35%	N/a	38%
SEC (GJ/t ethylene)[g]	18.8-20 (best) or 21.6-25.2 (typical)	18 (with gas turbine); 21 (typical)	21 (best)	20-25	No data

[a] For the conventional naphtha steam cracking, ethylene yield is typically 30%. HVCs yield is typically 55%.
[b] Technip data come from [31, 92]. According to Technip, SECs vary depending on the processing scheme, extent of heat integration amd climatic conditions [92].
[c] ABB data come from[31]; Other yields are 14.4%, butadiene 4.9% and aromatics 14%. The total HVCs yield is 60.7%. Gas turbine data based on [43].
[d] Linde data come from [31];
[e] Stone & Webster data come from [31, 93, 94];
[f] Kellogg & Brown Root come from [31, 95];
[g] The average SEC in the industry today is around 26-31 GJ/t ethylene for naphtha cracking.

Table 5 Catalytic and Alternative Olefin Technologies Using Conventional and Heavy Feedstocks[a]

	Gas Stream Technologies[b]	Ethane Oxidative De-hydrogenation[c]	Propane Oxidative dehydrogenation[d]	Catalytic cracking of naphtha[e]	Hydro-pyrolysis of naphtha[f]	Byproduct upgrading (C4-9)[g]	Catalytic Pyrolysis Process (CPP)[h]
Feed stock	Ethane and other gas feedstock	Ethane and oxygen	Propane and oxygen	Naphtha	Naphtha	C4-C9 (from steam cracking, refinery, etc.)	Crude oil, refinery heavy oils, residues, atmospheric gas oil, vacuum gas oil
Olefin s	Ethylene	Ethylene	Propylene	Ethylene/propylene	Ethylene	Propylene	Ethylene/propylene
React or	Shockwave, combustion gas; shift syngas; plasma; etc.	Alloy Catalyst Reactor with hydrogen co feed	Both a stem reformer and an (oxy-reactor); or, cyclic fixed-bed	Fluidized bed	Reactors with hydrogen co feed but less steam	Fixed or fluidized bed	Riser and transfer line reactor
Cataly sts	N/a	Mordenite zeolite	Zinc and calcium aluminate based	Zeolite (or various metal oxides)	N/a	Zeolite	Acidic zeolite
Temp. ^{o}C	625-700	900-1100	550-600	600-650	785-825	580-650	600-700
Total energy use[i]	Shockwave: ca. 8-10 GJ/t ethylene/HVCs	Dow: ca. 10-12 GJ/t ethylene/HVCs	Uhde: ca. 8-10 GJ/t propylene; ca. 8-10 GJ/t HVCs	KRICT: ca. 19 GJ/t ethylene and ca. 10 GJ/t HVCs	Blachownia: ca. 16-20 GJ/t ethylene and ca. 10-13 GJ/t HVCs	N/a	CPP: ca. 35 GJ/t ethylene and ca. 12 GJ/t HVCs
Yield (wt. %)[j]	Shockwave: highest ethylene yield ca. 90%	Dow: ethylene yield on the mass basis is ca. 80%	Uhde: propylene yield on the mass basis is ca. 84%	KRICT: ethylene 38%, propylene 17-20%, aromatics 30% and HVCs 73%	Blachownia: Ethylene yield 36-40% and HVCs yield 70%	UOP: propylene yield from steam cracking is 30% and HVCs yield 85%	CPP: ethylene 21%, propylene 18%, C_4 11%, aromatics 15% and HVCs yield 60%
Curren t status	Lab	Lab	Commercially available	Pilot plant	Commercially available	Commercially available	Lab and near commercialization

[a] Steam cracking has large, tubular fired furnace; feedstock is indirectly heated; no catalysts use in pyrolysis; temperature 750-1100 ^{o}C; no hydrogen or oxygen need. Process energy by the average naphtha cracking technology is ca. 9 GJ/t naphtha.

[b] Gas stream data come from [55]. Shockwave data come from [56]. Combustion gas could save 0.3 GJ/t ethylene [96].

[c] Per pass ethylene yield on the mol basis is typically ca. 30%. Data is based on [97, 98]. Oxygen production needs 3-4 GJ/t oxygen and this is accounted.

[d] Per-pass propylene yield on the mol basis is typically ca. 30-40%. Data is based on [84, 85]. Oxygen production needs 3-4 GJ/t oxygen and this is accounted. Propane steam cracking has a SEC of 20-25 GJ/t ethylene and 15-18 GJ/t HVCs with the yields of ethylene 42% and propylene 11% [30]. Other similar processes include Oleflex by UOP, Catofin by ABB Lummus, etc.

[e] KRICT data is based on [63]. Also, LG claims ethylene up by 20% yield and propylene yield up by 10% and 10% energy savings on the current SECs of naphtha cracking in Korea [68, 99]. The SEC 7.5 GJ/t naphtha is assumed based on [67]. Other processes are: AIST ethylene/propylene yield together 60-70% and 20% energy savings per ton of ethylene and propylene is claimed [40, 67]. VNIIOS ethylene yield 30-34% and propylene yield 18-20% [100]; Asahi ethylene 22%, propylene 20-40% [34].

[f] Hydro-pyrolysis was used in Blachownia Chemical Works in Poland, which claims a 20% increase of the average ethylene yield and ca. 30% less energy use [59]. The technology is not offered by major licensors.

[g] Olefins upgrading data is based on [82] and [22]. A similar industrial process is Metathesis [101]. Metathesis is an olefin conversion process, which in this case converts ethylene and butane-2 to propylene [13]. It is basically an extension of naphtha cracking to increase the yield of propylene.

[h] CPP data comes from [60, 61, 94]. The SEC 7.5 GJ/t feedstock is estimated. A review of several similar processes can be found in [64].

[i] Typically, current ethane cracking has an average SEC 17-21 GJ/t ethylene and 16-19 GJ/t HVCs. Naphtha cracking has a SEC 26-31 GJ/t ethylene and 14-17 GJ/t HVCs. The state-of-the-art naphtha cracking has 20-25 GJ/t ethylene and 11-14 GJ/t HVCs.

[j] Typically, ethane cracking has 81% ethylene yield. Naphtha cracking has 30% ethylene and 15% propylene yield.

Plenary session
Management and monitoring of energy efficiency

ENERGY AUDITING FOR IPPC FACILTIES IN IRELAND

Michael Gerard Owens MSc, Inspector
Office of Environmental Enforcement
Environmental Protection Agency

ENERGY AUDITING FOR IPPC FACILTIES IN IRELAND

Michael Gerard Owens MSc, Inspector, *Office of Environmental Enforcement, Environmental Protection Agency*

ABSTRACT

Since 1999, energy auditing has been a mandatory requirement of IPPC licences issued by the Irish Environmental Protection Agency (EPA). Licensed sites are now obliged to carry out an energy efficiency audit of their facility. In 2003, the EPA published a guidance note on energy efficiency auditing to facilitate a consistent approach to the audit process. It is also a requirement of the IPPC licence for any recommendations arising from the energy audit to be incorporated into site's environmental management programme (EMP).

1 INTRODUCTION

The rapid growth in Irelands economy over the last ten years has seen a rapid increase in both total, and per capita, energy consumption (figure 1). The industry and services sectors increased their consumption of energy by 15% between 1998 and 2002 alone, together representing 34% of all final energy consumption by 2002.

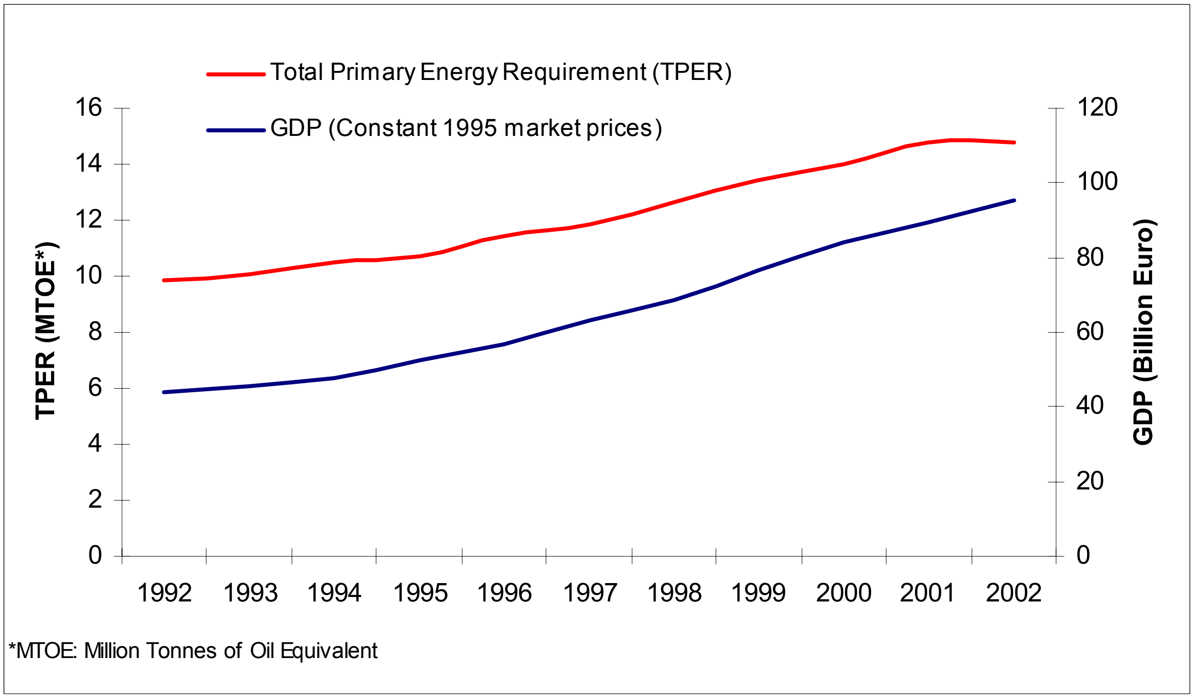

Figure 1 - Energy Demand and Economic Growth in Ireland 1992 – 2003

Energy in Ireland is still largely derived from non-renewable fossil fuels, especially oil (figure 2). Consequently, greenhouse gas emissions (GHG) have increased with energy demand in Ireland. The energy-generating sector alone, emitted 25% of total GHG in 2002, the remainder being accounted for mainly by the agricultural, transport and residential sectors.

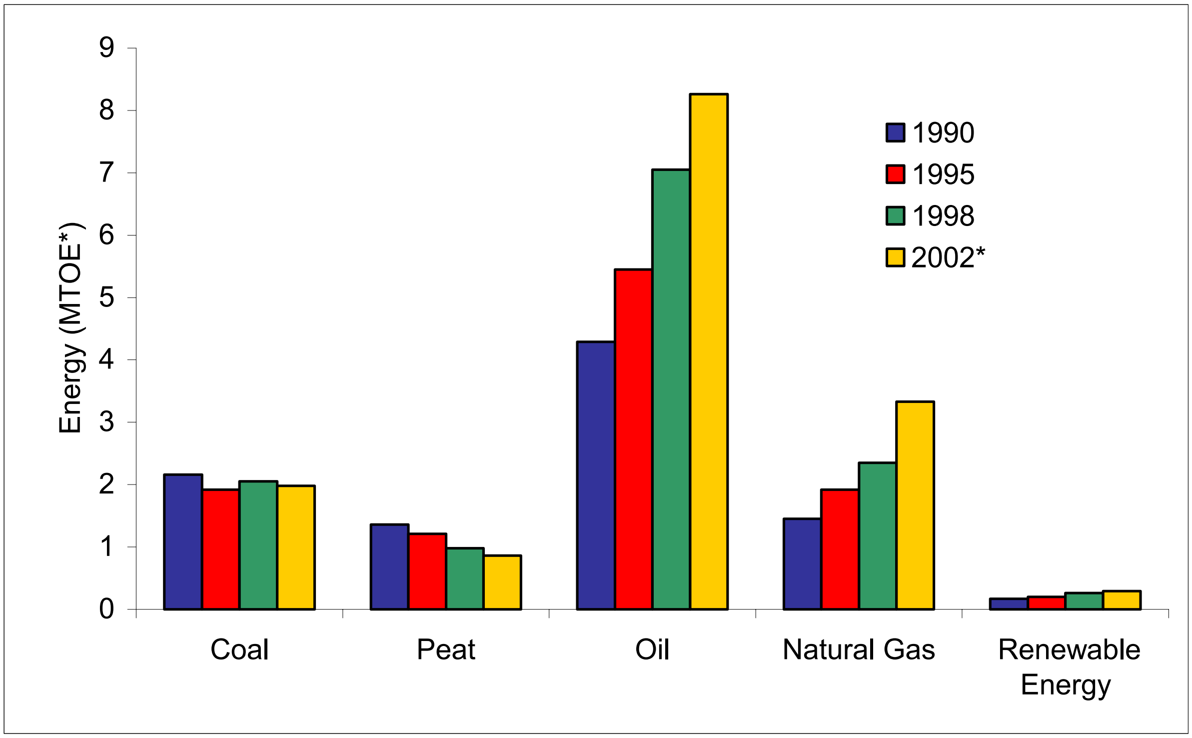

Figure 2 - Sources of Energy Supply In Ireland 1990 - 2002

2 INTEGRATED POLLUTION CONTROL (IPC) LICENSING

In Ireland, one of the principal policy responses to regulating industrial pollution was the introduction of Integrated Pollution Control (IPC) licensing in 1994. All aspects of a site's potential environmental impact are covered in the licensing process. Along with setting emission limit values, this type of licensing system requires companies to install an environmental management system (EMS) and to define targets, objectives and indicators for improving environmental performance on a continual basis. Currently there are about 500 industrial facilities licensed by the EPA.

This number includes all power plants greater than 50 MW. As a result, these energy sector licensees are required to have regard to energy efficiency throughout all of their operations.

3 INTEGRATED POLLUTION PREVENTION AND CONTROL (IPPC) DIRECTIVE

The Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EC) was transposed into Irish National Legislation in 2003. At present the EPA is reviewing all current IPC licences so that they, and all new licences, will meet the requirements of the directive.

Until 1999, energy auditing was not a mandatory requirement of IPC licences issued by the EPA. However, in anticipation of Articles 3, 6 and 9 of the IPPC directive, new conditions were included from 1999 onwards. These conditions introduced for the first time in Ireland an obligation to carry out energy efficiency audits at licensed sites.

The conditions were as follows:

- *The licensee shall carry out an audit of the energy efficiency of the site within one year of the date of grant of this licence. The licensee shall consult with the Agency on the nature and extent of the audit and shall develop an audit programme to the satisfaction of the Agency. The audit programme shall be submitted to the Agency in writing at least one month before the audit is to be carried out. A copy of the audit report shall be available on-site for inspection by authorised persons of the Agency and a summary of the audit findings shall be submitted as part of the Annual Environmental Report. The energy efficiency audit shall be repeated at intervals as required by the Agency.*

- *The audit shall identify all opportunities for energy use reduction and efficiency and the recommendations of the audit will be incorporated into the Schedule of Environmental Objectives and Targets.*

4 ENERGY EFFICIENCY AUDITING

An energy efficiency audit is a practical and valuable way to establish accurate and up-to-date information with regard to the current energy consumption patterns at a site. Essentially, an energy audit is a study to determine the quantity and cost of each form of energy to a building, process, manufacturing unit, piece of equipment or a whole site over a given period. The implementation of regular audits should be an important part of a sites energy management system.

5 DEVELOPMENT OF GUIDANCE NOTE

In response to enquiries from licensees, the EPA undertook to develop a guidance note to assist licensees in their interpretation of the relevant conditions. The guidance note on energy efficiency auditing was published in 2003. The note provides guidance to licensees on how to conduct consistent and effective energy audits at their facilities. The note was designed to be generic and horizontal in nature so that almost any industrial site could use it and that either an on-site operator or contractor could undertake the audit process. In addition, the note acts as source of information on energy management and provides a list of relevant websites and reference documents.

The note encourages a continuous cyclical auditing process, much like an environmental management system (i.e. measure, plan, act, review…etc.). Site operators can use the results of an energy audit to identify recommendations and actions for energy efficiency improvements at a site. In addition, the note offers guidance to site operators in quantifying actions in terms of energy savings, cost savings and return on investment.

6 OVERVIEW OF GUIDANCE NOTE

The overall process is broken down into discrete steps, preparation, execution, analysis and reporting. Audit preparation involves designation of responsibilities, determination of the scope of the audit, i.e. which areas and systems to examine, and the collection of existing energy data for the site.

The execution of the audit itself involves comparing the sites existing energy management system with best practice and assessing each of the energy-consuming systems on-site. The note provides guidance and sample checklists to aid in these steps.

The energy performance of systems, or of the whole site, is assessed using appropriate energy performance indicators (EPI's). These indicators provide a means to quantify energy costs and consumption against important factors such as level of production or site occupancy etc. The sites energy performance can be benchmarked against EPI's from other sites. These other sites can be either from the same organization or the same sector.

Following these steps, a set of recommendations is identified for improving the energy performance of the site. A list of recommendations is selected for implementation with each element being allocated responsibility, a target date and sufficient resources. It is a requirement of the IPC licence that the final recommendations be incorporated into sites environmental management programme as objectives and targets.

The performance of the implemented recommendations are monitored, recorded and incorporated as inputs into the next energy audit, thus applying the loop of continual improvement.

Finally, it is a licence requirement that two reports be prepared for each energy audit.

- Main report - to be maintained on-site
- Summary report – to be submitted to the EPA as part of the sites Annual Environmental Report

7 CONCLUSION

The response from industry to the guidance note has been positive. But it is too soon yet to say what impact the guidance note will have on Irish industry in terms of efficiency of energy use. Its probably fair to say at this point that the IPC licensing system so far has had a positive impact on the industrial and energy sectors in Ireland with regard to energy efficiency over the last ten years. Current statistics on the eco-efficiency of these sectors seem to support this (figures 3 and 4) and seem to suggest that the development of a lower energy intense economy in Ireland has begun.

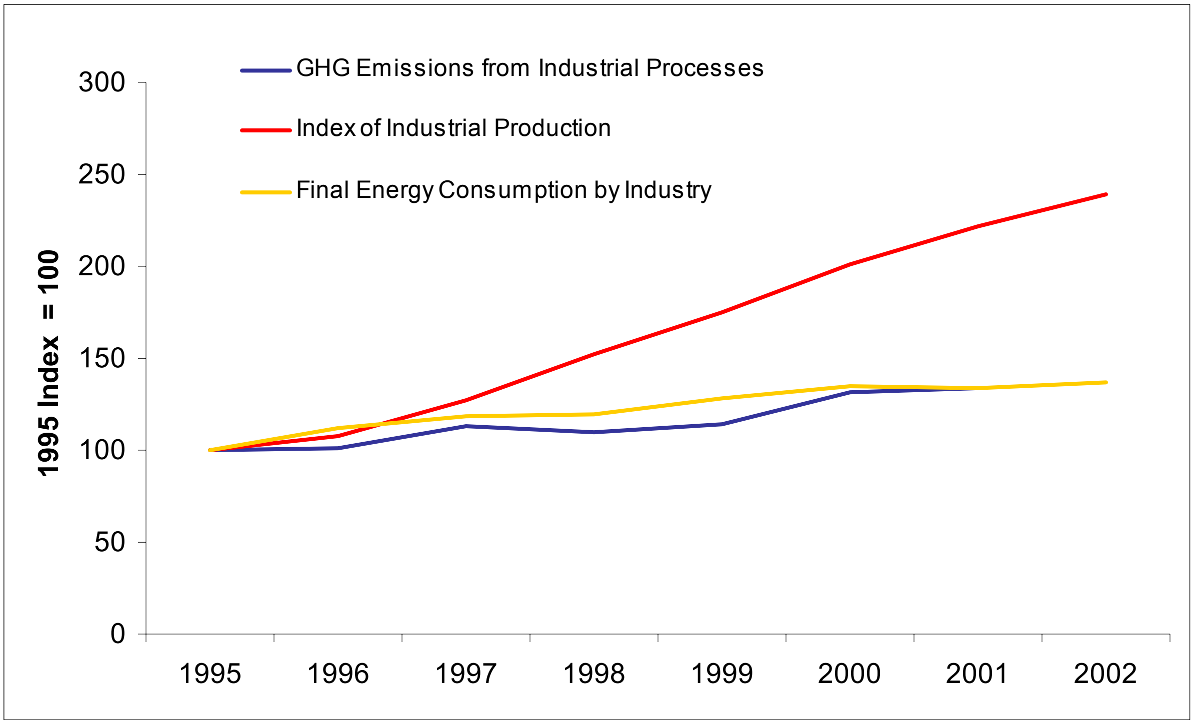

Figure 3 - Eco-Efficiency of the Industry Sector in Ireland 1995 – 2002

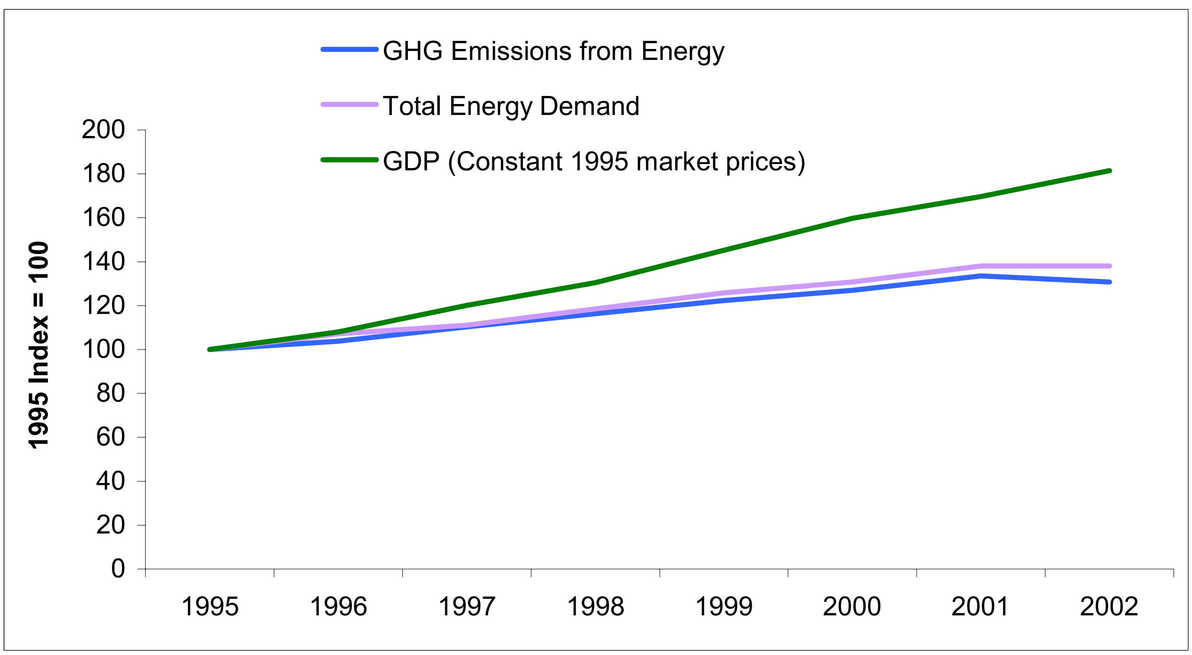

Figure 4 - Eco-Efficiency of the Energy Sector in Ireland 1995 – 2002

A copy of the guidance note can be down loaded for free from the Agency's website at www.epa.ie. It can be found under http://www.epa.ie/NewsCentre/ReportsPublications/Guidance/.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

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Plenary session
Management and monitoring of energy efficiency

ENERGY MANAGEMENT AS A EUROPEAN WIDE STANDARD FOR CONTINUOUS IMPROVEMENT

Rainer Stifter
ENERGON
Jasomirgottstraße 6/7A, 1010 Vienna, Austria
E-mail: rainer.stifter@energon.co.at

ENERGY MANAGEMENT AS A EUROPEAN WIDE STANDARD FOR CONTINUOUS IMPROVEMENT

Rainer Stifter, *ENERGON*

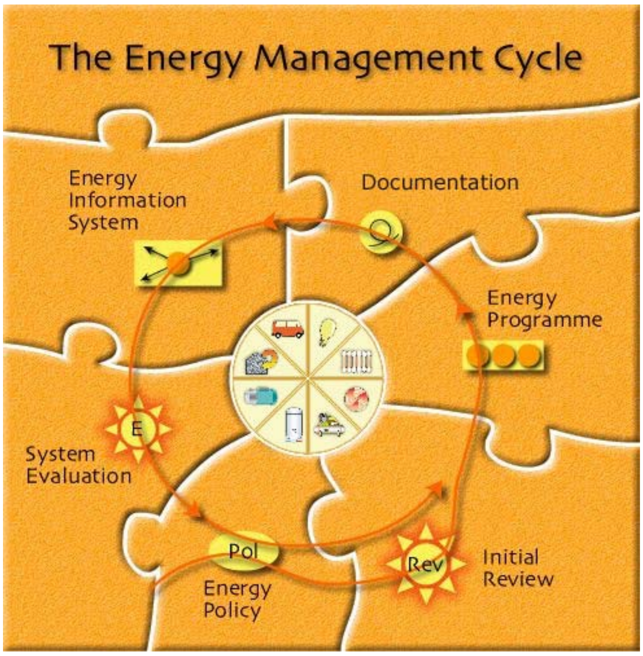
Supporting European Policies on standardisation and on a systematic approach to energy efficiency

Establishing and maintaining a company's market position involves more than financial considerations. A key to successful business is being able to forecast future developments in many areas, including the environment and human resources management. Energy Management will assist in the development of a sound strategy in these two areas.

Although an Energy Management System covers all aspects of an energy system within an organisation, up to now there is no standard in place for continuous improvement. There have been several initiatives from different groups including the DG Environment; however, it seems that a harmonised approach is not easy to reach.

The Energy Management System developed by the team of ENERGON presents a standard which (i) was already implemented within several industrial sites in Europe, (ii) results in significant savings (iii) was incorporated in an energy guideline which will be published in 2005 by the DG Environment, (iv) will be used for training material to achieve an energy management licence. The training material was developed under the Leonardo framework and will be offered for the first time this year at the BFI Vienna.

An energy management system, like all other management systems, is cyclical in nature. It is a formal system which requires the support at all levels within the company. Once implemented it offers a structured approach to dealing with energy issues and is the basis for continuous improvement.



The key features in this process are incorporated in the cyclical process

Energy manager
There must be somebody appointed to undertake the energy analysis and for continuously improving the efficiency of the system. In particular, when starting a review the activities will take some time and the energy manager must have the clear commitment from the senior management. Larger organisation will require a team with team members from different departments, covering the individual energy topics such as purchas, main energy consumers and maintenance.

Energy Policy
The development of an energy policy is the starting point for an effective energy management. The policy is integrated into the business policy and is a clear statement of intention and direction. Besides the written document it is important to underline the development process itself. Often for the first time the energy team will discuss strengths and weaknesses, interdependencies between departments and possible future developments.

Initial Review
The review explores the company's current position on energy, including energy consumption and costs. It includes a

- Goal definition which defines the scope of the analysis. This can include a general review, the investigation of unusual losses, the company's position in relation to bench marks as well as organisational aspects influencing consumption.
- System boundary definition to identify areas that are to be included and excluded from investigations.
- Systematical data collection and measurements; This is essential as unstructured or poor data will be meaningless for continuous monitoring.
- Input-Output analysis to get a clear picture about the company's overall position
- Flow chart of the inner energy flow in an organisation to give a detailed picture of the main consumers and costs

Energy Programme
On a regular basis the energy team has to develop an energy programme. The information is needed to present a clear idea about actions and requirements to be fulfilled by the staff.

Documentation
The Energy Management System is a formal system. Therefore the whole system must be described in a handbook. The handbook presents the system and information must be given to explain the main features. The manual is not a standardised document but should present the individual components of the energy management system in place.

Energy Information System
The information system includes a

- Energy bookkeeping system, summarising the core data, helping to monitor energy costs and comparing the baseline with improvements
- Energy report including success stories for energy savings, the energy programme, indicators and key figures. The report should help interested groups to understand the system and to evaluate the success of energy saving activities

System Evaluation
An Audit, undertaken by staff or external specialists, will show the energy team that all components of the Energy Management System work properly, such as working procedures to ensure low energy input, improvement proposals, service activities, the purchase of energy saving equipment. The audit results will be presented to the general management and should help to undertake future energy saving activities with the full support of everybody in the organisation.

Evidence suggests that if energy use has not been looked at for some time, companies can make savings of between 10 and 20% on their energy bill by simple actions which have quick pay back periods and that companies already focusing on energy saving activities may make savings of about 3 % of their total energy costs during the first few years after implementation.

Plenary session
Management and monitoring of energy efficiency

ENERGY, RESOURCE AND WASTE MANAGEMENT: THE SWEDISH SECTOR

Ahmadzai Husamuddin
Swedish EPA
Http://www.naturvardsverket.se

NATUR VÅRDS VERKET

Energy, Resource and Waste Management The Swedish Sector

Tekn Dr Husamuddin Ahmadzai

Swedish EPA

Http://www.naturvardsverket.se

NATUR VÅRDS VERKET

Swedish Environmental Goals

In 1999 the Parliament adopted 15 quality objectives for long term sustainability:

- Climate
- Clean air
- Natural acidification
- Non-toxic environ
- Stratospheric Ozone
- Radiation
- Mountain landscape
- Eutrophication
- Lake and rivers
- Ground water
- Marine & coastal env
- Wetlands
- Forests
- Agriculture
- Habitat

NATUR VÅRDS VERKET

Introduction 1/2

About 25% of total GHG emissions (ca 73 M t CO_2-eq) emanate from industry.

Approximately 80 % of CO_2 emanating from the industrial sector is from the energy intensive industry:

	Mt CO_2
Metal production (Fe & non-Fe):	4,2
Paper industry:	2,9
Mineral industry:	2,8
Fossil, fuel, district heating, waste, refinery products:	2,1

The energy intensive industry consumes ca 70% of total industrial consumption of El (54 TWh)

The energy intensive industry gives rise to 99 % of waste (of total 73,1 M t (2002).

NATUR VÅRDS VERKET

Introduction 2/2

Mining & Metallurgical industry in Sweden

- Is a production leader in EU-15 & EU25 in Fe, Top 3 in EU-25 for Cu, Pb, Zn
- Primary and secondary (iron & steel)
- Primary and secondary non-ferrous (Al, Cu, Pb, ZnO, refractory metals, ferro-alloys)

NATUR VÅRDS VERKET

Instruments

Combination of legislative, economic and information exchange:

- Environmental Legislative Framework
- Carbon and energy taxes, NOx levies
- Investment incentives (LIP, KLIMP), remediation programmes
- Green certificates
- Quality certification (EMAS, ISO)
- Emission Trading, JI, CDM
- Sectoral approaches (voluntary programmes)
- Information campaigns

NATUR VÅRDS VERKET

Environ. Law Framework

In force since 1 January 1999

Rules of consideration:

- Knowledge
- BAT
- Site selection (Environment, human health)
- Conservation of RM, Energy, Recycle. Renewables
- Chemical products
- Reasonable costs and benefits
- Remediation
- Activity restriction

NATUR VÅRDS VERKET

Best Available Techniques

- About 1000 IPPC installations addressed by the IPPC Directive 96/61/EC.
- About 600 installations addressed by the Emission Trading Directive 2003/87/EC.
- National cap 22,9 M t CO2. 30% of total CO2 emissions

NATUR VÅRDS VERKET

Metals, Resource Use, & the Environment. Challenges

Metal consumption (kg/capita-year)

	1995	2020	%-change
Sweden	370	240	- 35
Global	125	185	+48

NATUR VÅRDS VERKET

Metal Resources

Percent metal consumption in Sweden based on recycled material

Metal	1995	2020
Al	50	75
Cu	40	75
Fe	85	90
Pb	50	95
Overall Total	80	90

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Potential for Improvement

Environment & Energy. Metal Produced & Consumed in SE

Parameter	Unit	1995	2020	Percent
NOx	t/y	4800	1500	- 70
S	t/y	3400	800	- 75
Dust incl. HM	t/y	2600	400	- 85
CO2 (marg)	t/y	10 M	3 M	- 70
Total Energy	PJ/y	54	20	- 60

NATUR VÅRDS VERKET

Conclusion (1/3)

- Key Swedish energy intensive sectors, including metallurgical sector by 2020 have undergone structural changes.
- Product development, increased energy prices and more effective use of energy and recycling are expected to play a key role.

NATUR VÅRDS VERKET

Conclusion (2/3)

- Total specific energy requirement for primary metal production is highest for aluminium compared to steel and copper. Specific energy requirement for secondary metal recycling is highest for steel.
- Demand for aluminium is expected to increase. Energy prices are expected to increase by 2020 whereby production of primary aluminium in Sweden would be threatened unless new technology and investments are made.

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Conclusion (3/3)

- Investment constraints may result in secondary aluminium replacement of primary Al-production.
- By 2020 it is expected that structural changes, application of contemporary BAT, more efficient energy utilisation, compatible and flexible environmental tools, such as Emission Trading (JI & CDM) have reduced specific releases of CO_2, NO_x, SO_x, Hg, Cd to levels facilitating sustainable development.

Plenary session
Assessment of energy reduction potential in industry

COMBINING IPPC AND EMISSION TRADING: ENERGY EFFICIENCY AND CO2 REDUCTION POTENTIALS IN THE AUSTRIAN PAPER INDUSTRY

Otto Starzer
E.V.A. – The Austrian Energy Agency
Otto-Bauer-Gasse 6, 1060 Vienna, Austria
Email: starzer@eva.ac.at, phone+43 1 586 15 24-19

COMBINING IPPC AND EMISSION TRADING: ENERGY EFFICIENCY AND CO2 REDUCTION POTENTIALS IN THE AUSTRIAN PAPER INDUSTRY

Otto Starzer, *E.V.A. – The Austrian Energy Agency*

ABSTRACT

In the frame of an innovative project partnership E.V.A. – the Austrian Energy Agency accompanied the Austrian paper industry for the last two years in developing a branch specific climate change strategy. Within the scope of this project an assessment of the energy efficiency status of the branch was carried out as well as an evaluation of still realisable energy savings and CO_2 reduction potentials.

The paper presents the methodology applied, which combines a top down approach (benchmarking & best practice) with a bottom up approach (on-site interviews & energy audits), supported by a huge data collection process.

Within the benchmarking process all Austrian paper industry installations affected by the EU emission trading directive were benchmarked against their respective BAT values (from IPPC/BREF document). Furthermore an extensive list of best practice examples derived from existing or ongoing studies was compared with the energy efficiency measures already carried out by the companies (“early actions”).

These theory-oriented findings were complemented by several on-site interviews with the respective energy managers as well as by detailed energy audits carried out by a consulting company, covering in total more than 80 % of the Austrian paper industry’s CO_2 emissions.

The paper concludes with the main results of the project, presenting also the pros and cons of working with IPPC (BREF) documents and BAT values [IPPC 1996] in terms of energy efficiency assessments.

1 Introduction – Emission trading and the IPPC / BAT

With the adoption of the EU wide emissions trading scheme (COM(2001)581 final) to reduce GHG emissions [EC 2002] a new instrument entered the "energy efficiency market" creating a need for integration within the existing policy mix.

Within the EU emission trading scheme each concerned installation will receive absolute emissions allowances, which were reported to the EC in the so called national allocation plan (NAP). The time before 31 March 2004, the deadline for the first NAP covering the period from 2005-2007, was very turbulent almost in all EU countries, since negotiations between authorities and industry on how to agree on absolute emissions targets are a very "delicate" matter. For the industrial companies it meant for the first time that they got a cap on their emissions which could effect their economical growth considerably. Thus they were tending to get as many allowances as possible not to limit possible production increases.

For the authorities on the other hand it was important to make the system work and to achieve high environmental benefits. National governments had to consider that the allocation plan should be consistent with the targets of their national climate change programmes as well as with the obligation under the EU burdon sharing under the Kyoto protocol. They had also to make sure that the quantities of allowances match the actual (technological) potentials.

Of course this led to conflicting situations between industry and authorities and therefore transparent information on the available potentials was of utmost importance. This was the time when the IPPC directive and the BREF documents with their respective BAT values (best available technologies) could play an important role [IPPC 1996]. The BAT values represent EU-wide accepted benchmarks which could be taken as an indicator for existing energy efficiency potentials. How this benchmarking process was applied in the case of the Austrian paper industry is explained in this paper.

In the frame of an innovative project partnership E.V.A. accompanied the Austrian paper industry since 2002 in developing a branch specific climate change strategy [Starzer et al 2004]. This included an assessment of the energy efficiency status of the branch, as well as an evaluation of still realisable energy savings and CO2 reduction potentials. The project was closely connected to the EU emission trading scheme, since future potentials were considered as crucial for the amount of emissions allocated.

2 Methodology to evaluate the Energy efficiency status of industry

How to consider energy efficiency when allocating CO2 emissions? To answer this question E.V.A. developed a transparent methodology on how to evaluate energy efficiency potentials [Starzer et al 2003]. In the course of this project a transparent process was proposed to verify technological potentials including benchmarking, best practice and audit elements (see figure 1).

Figure 1: Framework for agreement process including Benchmarking, Best Practice and Audits.

In order to identify the technological potential of concerned emission trading installations a two-fold approach was applied:

On the one hand a theoretical top-down approach was followed:

Based on a comprehensive data analysis of all energy and CO2 related data of an installation – which was anyway necessary for the allocation process – benchmarks were developed for each comparable type of installation. This work was based on previous experiences gained within several EU SAVE II projects [IEC 2001, BPI 2002]. In many cases the values presented in the BAT documents (best available technologies) of the IPPC directive [IPPC 1996] served as master benchmarks to define what is the best value. It is important that the benchmarks take into account the thermal as well as the electricity consumption. Then the distance from the best value was distinguished and served as a first indication on the technological potential.

However, it is essential to know that benchmarking is not a perfect instrument. It can only indicate the general tendency. Therefore in parallel checklists of theoretically possible best practice measures were developed, based on the knowledge of the most recent potential studies in the EU [Haworth 2000, Drasdo 2000, Martin 2000, Alsema 2001, De Beer et al 2001]. By commenting this check list the companies pointed out which measures they already accomplished since 1990 (early actions) and which are still open to be realised. Pay back time was an important criteria to justify that measures are not yet undertaken.

On the other hand a practical bottom-up approach was followed:

To be able to compare the theoretical results with "real life", the companies undertook energy audits in order to show the realistic potentials applicable on their site. The audits were carried out by a consultant (in the most cases by ALLPLAN). The audit has to follow clearly defined audit procedures, to ensure the quality and comparability of the results [Väisänen et al 2003]. This will ensure that transparent emissions allowances are considered in the national allocation plans. Thus E.V.A. was able to check all audit reports and had detailed talks with the respective project managers of the consultant. E.V.A. also carried out on-site interviews with the responsible company staff, in order to ensure the quality of the results.

3 The benchmarking process

In the course of the national discussions when developing the national allocation plan benchmarks were seen as suitable means to derive emissions allowances on an installation basis. By comparing internationally valid indicators the Austrian companies should be judged whether they had done their energy efficiency "homework" and whether early actions could be taken into account. This approach takes into account the fact that in Austria (and in many other countries) not many comparable sites by type of installation do exist.

In the course of the project a set of indicators was derived using branch specific values and approaches. Installations were distinguished by production, i.e. whether they represented pulp, paper or integrated mills. Furthermore different types of pulp as well as different types of products had to be distinguished to develop a useful set of indicators. For each indicator the thermal and the electricity consumption were related to the relevant production data (see table 1).

Table 1: Schematic suggestion for a set of indicators

Type of installation	electricity	heat	CO_2
integrated production	MWh / tonne of paper	TJ / tonne of paper	CO2 / tonne of paper
pulp production	MWh / tonne o pulp	TJ / tonne of pulp	CO2 / tonne of pulp
paper production	MWh / tonne of paper	TJ / tonne of paper	CO2 / tonne of paper

A special problem presented the system border in terms of energy losses. In a first attempt all energy losses were included within the benchmarks. Thus the indicator was calculated by using the primary energy consumption, initially the heat benchmark was calculated with the fuel heat minus the own production, the electricity benchmark with the electricity consumption, including own production and imported energy (see figure 2).

Figure 2: Calculation of heat and electricity indicator (first attempt)

In the course of the project this method was changed because of two reasons: firstly, to make the data and results compatible with the data collection project of the UBA / IIÖ, carried out to support the ministry in the preparation of the allocation plan. And secondly, the investigation of the BREF document [IPPC 2001] made it necessary to modify the process to be able to use the published benchmarks for comparison.

It was concluded that a third benchmark should be calculated to compare the efficiency of the energy production process (production of process heat, district heat and electricity related to primary energy consumption). Thus the benchmarks for electricity and process heat consequently included only the energy consumption used for the paper and/or pulp production process.

Due to the lack of information within the BAT documents concerning system borders some open questions are still remaining. It is not clear whether the energy consumption always is calculated without energy losses, or if sometimes the energy losses are included e.g. for integrated plants. Of course this might lead to completely different benchmarking results. For plants with black liquor recovery system only the produced heat should be taken into account for the benchmark.

According to the above mentioned procedure the Austrian paper mills were put into different benchmarking groups and by using confidentially reported data a benchmarking comparison was carried out for all emission trading installations. The different benchmarking groups and the BAT benchmarks derived from the BREF document [IPPC 2001] are presented in table 2. Possible process related differences had to be evaluated individually.

Table 2: Benchmarking Groups for the Austrian paper mills (source: [IPPC 2001])

	Benchmarking group	**BAT electricity kWh/t**		**BAT process heat GJ/t**	
Mechanical Pulp		from	to	from	to
Integrated					

	Newsprint (>50% mechanical pulp)	2000	3000	0	3
	LWC mill (> 50% mechanical pulp)	1700	2600	3	12
	SC mill (> 50% mechanical pulp)	1900	2600	1	6
Kraft (Sulphate) Pulp					
Non-integrated					
	Bleached Kraft pulp	600	800	10	14
Integrated					
	Kraftliner, unbleached	1000	1300	14	18
	Sackpaper, unbleached	1000	1500	14	23
Sulphite Pulp					
Non-integrated					
	Bleached sulphit pulp	700	800	16	18
Integrated					
	Bleached sulphit pulp and coated fine paper	1500	1750	17	23
	Bleached sulphit pulp and uncoated fine paper	1200	1500	18	24
Recovered paper processing					
	RCF based Testliner and Wellenstoff without de-inking	700	800	6	6,5
	RCF based cartonboard or folding boxboard, no de-inking	900	1000	8	9
	RCF based newsprint, de-inked	1000	1500	4	6,5
	RCF based tissue, de-inked	1200	1400	7	12
Paper production					
Non-integrated					
	Uncoated fine paper	600	700	7	7,5
	coated fine paper	700	900	7	8
	Tissue mill (process heat up to 25 GJ/a)	600	1100	5,5	7,5

4 Main results and conclusions

The benchmarks were discussed in detail with each company and possible mistakes could be corrected. The companies could chose whether they wanted to use these benchmarking results within the “distance to best practice” exercise carried out by IIÖ and UBA.

It can be concluded that the Austrian paper mills have very good results. In total 25 installations were included in the benchmarking process. Only in 3 cases the benchmarks for process heat were slightly higher than the BAT reference. In 4 cases the electricity benchmark was out of the BAT range. Of these installations one was out of both heat and electricity ranges.

One possible explanation is that plants might have reported wrong energy consumption data (e.g. high instead of low pressure values). A correction lowers the process heat indicator considerably. High differences from BAT reference values only were found among some companies where the product spectrum differed considerably from the spectrum used for the BAT reference. In these cases the BAT values are not representative. Differences also can be explained by partly integrated plants, i.e. if only a part of the produced pulp is used for paper production on site or if additional (imported) pulp has to be added. This leads of course also to very different benchmarks.

By far the majority of plants was within the given range of the BAT reference. 13 plants even had better values then the lower BAT value (see column “from”, table 2). The same counts for 15 plants for the electricity benchmark. This might lead to the question whether the BAT references really present the best available technology. However, to be able to answer this question it would be necessary to compare the BAT references also with the benchmarks of paper mills from other EU countries. In any case, a revision of the BAT values and a clearer definition of the system borders can be recommended, especially if they should further be used in the international context such as for benchmarking exercises. And this could already happen in a couple of years when the next NAP has to be developed for the 2nd emission trading period 2008 to 2012.

The emissions trading scheme can actually present a strong driver towards industrial energy efficiency. The IPPC documents and their respective BAT references could play a crucial role in monitoring the effects of the EU emissions trading scheme, however, it needs credible and transparent benchmarks to do so and they have to be applied throughout the EU.

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6 About the author

Otto STARZER is mechanical engineer (M. Sc., Technical University Graz) and worked for several years in industry as project manager especially in the field of CHP plants (ABB, Elin) before he joined E.V.A. – The Austrian Energy Agency. Within E.V.A. he is Head of E.V.A.'s "Consumer/Demand Side" Unit and senior expert for rational use of energy (RUE) in industry. Furthermore he is the Austrian Contact Point for the European Energy Network (EnR), the network of national energy agencies in Europe. Mr Starzer is the project manager of the paper industry project titled "Chances of the paper industry in the framework of the climate change strategy".

Plenary session
Cross-cutting energy efficiency measures

ANALYSIS OF ENERGY EFFICIENCY MEASURES IN LATVIA - POTENTIAL OF EMISSION TRADING

Marika Blumberga, Dagnija Blumberga, Claudio Rochas
Riga Technical University, Department of Energy Systems and Environment
Email: dagnija@btv.lv

ANALYSIS OF ENERGY EFFICIENCY MEASURES IN LATVIA. POTENTIAL OF EMISSION TRADING

Marika Blumberga, Dagnija Blumberga, Claudio Rochas, *Riga Technical University, Department of Energy Systems and Environment*

ABSTRACT

Paper presents experience obtained during preparation of Latvian National Allocation Plan for 2005 – 2007. Authors worked out methodology of evaluation of potential operators, who could participate in emission trading. Several aspects were covered during this study.

- Operation data (Fuel and raw material consumption, energy and end-product production).
- Awareness and knowledge of participants about reduction of greenhouse gases.
- Energy efficiency measures implemented and planned.

Evaluation of existing technological measures to improve energy efficiency in IPPC installations showed high potential of reduction of greenhouse gases. Paper presents results of analysis in process of identification and assessment of energy efficiency measures in energy sources in Latvia.

Introduction

To help prevent global climate change, in implementation of the United Nations Framework Convention on Climate Change with its Kyoto Protocol and the European Union's climate change legislation, Latvia prepared the National Allocation Plan for period 2005 … 2007, showing the principles of allocating allowances for greenhouse gas emissions, amendment of legislation and the potential for decreasing greenhouse gas emissions. The preparation of the National Allocation Plan was regulated by European Union Directive 2003/87/EC, establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC ("Directive 2003/87/EC").

The National Allocation Plan [1] has been drawn up in accordance with the instructions given in the Communication from the Commission on guidance to assist Member States in the implementation of the criteria listed in Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community and on the circumstances under which force majeure is demonstrated (COM (2003) 830 final).

Content of National Allocation Plan is based on analyses of the existing normative acts, statutory laws, national programmes, plans and other official documents (including bills) of the Republic of Latvia, as well as studies of the work of emissions traders and the quantities of greenhouse gases (GHG) emissions from 1993 to 2002.

Kyoto Obligations of Latvia.

The Parliament of the Republic of Latvia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and the Kyoto Protocol to the Convention in 2002. Latvia has therefore undertaken to fulfil a number of obligations. According to the Kyoto Protocol, Latvia has to decrease its GHG emissions by 8% below 1990 levels.

In 1990 Latvia emitted 29 107 Gg of CO_2 equivalent[1], so in order to meet its international obligations Latvia cannot exceed 92% of this level and emit more than 26 778 Gg of CO_2.

Taking into account the GHG emissions forecast to 2020, prepared for the Third National Communication in the framework of the UNFCCC ("the Third National Communication"), planned emissions in Latvia are considerably less than prescribed by the Kyoto protocol (see Fig. 1).

[1] Latvian Environment Agency data (inventory data prepared in 2003 for the UNFCCC Secretariat)

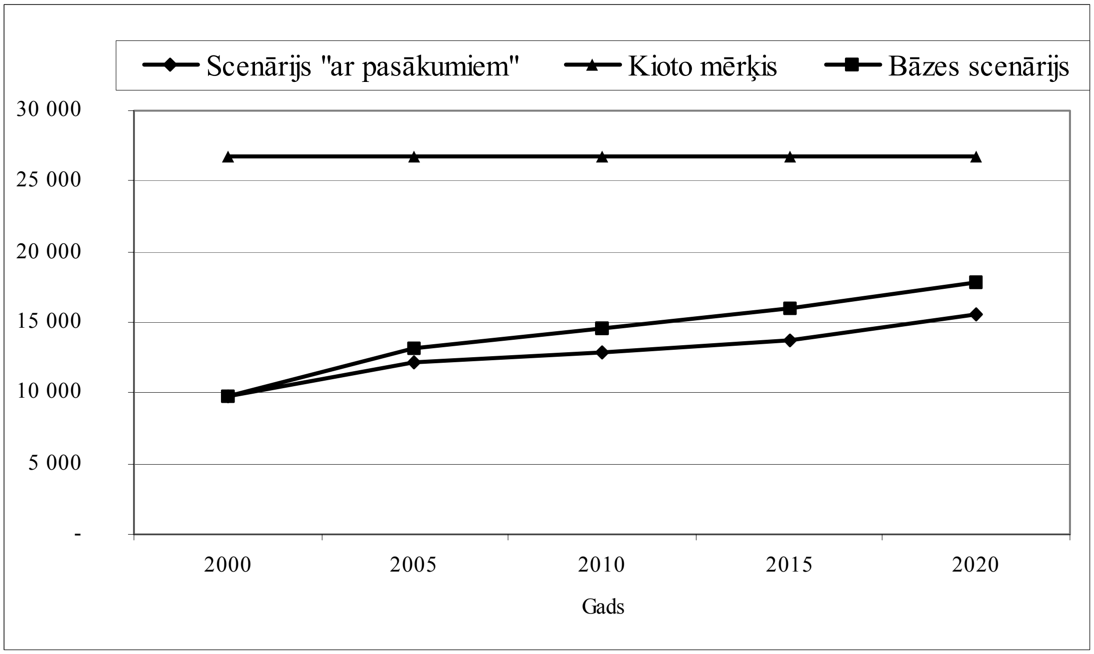

Fig. 1: Total GHG emissions in 2000-2020, Gg of CO_2 equivalent.
Translation key: "With measures" scenario; Kyoto objective; Basic scenario (without measures)

The forecast in the Third National Communication has been amended since the Latvian Environment Agency has corrected the data of historical emissions, so as a result the actual level of CO_2 emissions in 2000 is lower. In 2000 the total corrected quantity of GHG emissions in Latvia was 9 857 Gg of CO_2 (and not 10 892.26 Gg of CO_2), of which industries in compliance with Directive 2003/87/EC emitted 3 705 Gg of CO_2 (boiler houses and cogeneration plants 2 453 Gg, industrial companies 938 Gg, industrial processes 313 Gg of CO_2), which in total amounts to 38% of all GHG emissions in Latvia.

Participants of the emission trading scheme

The invitation of potential participants of emission trading scheme to take part in emission trading went out in several ways:

- a notice was published in the Latvian official newspaper and in the home page of the Ministry of Environment;
- a notice was sent to professional associations, to enterprises already operating with the environment management system;
- seminars were organised on emission trading issues;
- articles on the establishment of the National Allocation Plan appeared in two mass media publications.

Such advertisement and popularisation of opportunities resulted with 96 participants from Latvia. The emission trading scheme includes four polluting activities.

A. Energy activities:
  - ✓ 60 mandatory installations - combustion installations with a rated thermal input exceeding 20 MW;
  - ✓ 24 voluntary installations - combustion installations with a rated thermal input is less than 20 MW.

B. 1 mandatory installation in production and processing of ferrous metals.

C. 10 mandatory installations in mineral industry.

D. 1 mandatory installation - industrial plants for the production of paper.

There are several reasons for including voluntary installations, which are not in compliance with the conditions on load consumption:

- to popularise environmentally sound concepts, involving all interested operators in the emission trading scheme;
- to develop clean technologies in energy installations, involving all interested operators in the emission trading scheme.

On 7 April 2004 the Saeima adopted amendments to the Law on a Natural Resources Tax, which provide for the application of a differentiated CO_2 tax to an operator who has not transferred allowances corresponding to the quantity of GHG emitted in the previous calendar year, beginning in 2005, as well as tax relief for installations subject to CO_2 tax, which are participating in the allowance trading scheme as set out in the Law on Pollution. Analysis of CO_2 tax influence on energy efficiency measures is presented in article [2].

Operation data. Collection and processing

With regard to activities, the “bottom-up” approach is used for determining allowances. The total quantity of allowances is calculated by adding up all the operator allowances in the relevant activity groups.

To improve data credibility, output data are used for allowance calculations. Output data are determined using measuring instruments conforming to the following standards:

- a fuel measurement instrument, e.g. a natural gas meter;
- a heating meter at the outlet of a boiler house;
- an electricity meter.

For emission calculations for combustion installations, two equations are used [3]. Their usage depends on whether allowances were calculated from the amount of energy produced (equation 1) or from the quantity of natural gas consumed (equation 2):

$$CO_2 = \frac{Q \cdot R \cdot 100}{\eta}, \text{ t } CO_2\text{/year} \qquad (1)$$

where

Q - amount of energy produced (meter reading), MWh

R - emission factor, t CO_2/MWh

η - coefficient of efficiency, determined with measuring instruments during boiler regulation, %

or

$$CO_2 = B \cdot Q_d^z \cdot R \text{, t } CO_2\text{/year} \quad (2)$$

where

B - quantity of natural gas consumed, thousand m^3

Q_d^z - lowest calorific heat value of fuel, MWh/1000 m^3.

Example of analysis of data of one boiler house is presented in Figure2. Regression analysis of data presented by owners of boiler house shows that correlation is not good because of data in one year were much more lower than average. Experts stated reasons of dissipation and only after that was calculated number of allowances for period 2005 … 2007.

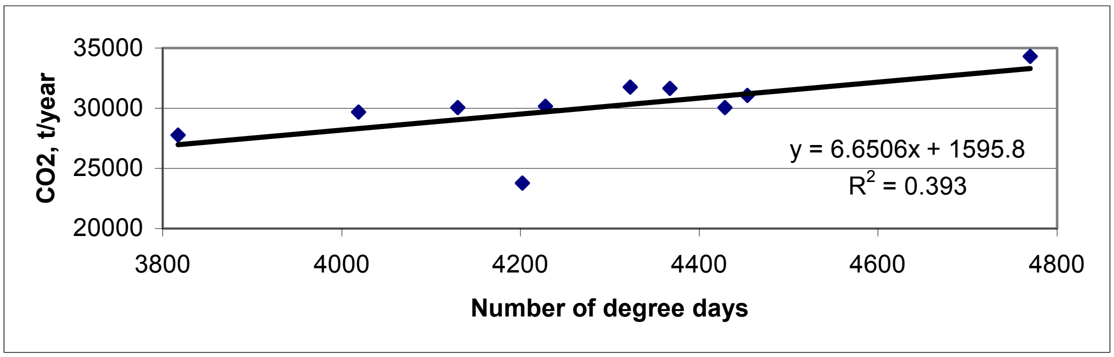

Fig.2. Example of analysis of data of one of energy installations

Industrial enterprises' emissions from boiler houses are calculated using equations 1 and 2, according to the kind of fuel used. However, emissions from technological processes are calculated for each sector separately, on the basis of Commission Decision 2004/156/EC establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

Reduction of greenhouse gas emissions

Methodology for modelling of possibilities to reduce GHG emissions includes list of potential activities and simulation model. The following measures to reduce GHG emissions in energy installations are included:

- fuel switch (replacing fuel with a higher emission factor by fuel with a lower emission factor);
- improving the energy efficiency of boiler installations;
- improving the arrangement of the heating network to reduce heat loss;
- improving consumers' energy efficiency.

In determining the amount of allowances for emission trading period 2005 … 2007, a simplified methodology offered by experts is used for determining the impact of early actions. This methodology takes into account only the reduction of GHG emissions gained by fuel switch projects. The methodology consists of analysing and collating operator output data. The operation, which results in improved efficiency of boiler installations, was viewed and analysed separately.

In addition, reduction of energy consumption by consumers was excluded from the GHG emission reduction measures performed previously. Such type of restrictions, which were stated in EC Directive are working opposite to demand side initiatives.

Corrections to account for differences in climatic conditions were incorporated in the methodology. In most cases, when 1997 was determined as the base year the GHG emissions reduction measures carried out were taken into account. Only in 6 installations had the first GHG emissions reduction measures been carried out before 1997. In these cases there were several additional limitations, so the reduction in GHG emissions can only be determined approximately.

Where the fuel switch was carried out before the base year, the reduction in GHG emissions was determined using equations 1 and 2 and, in addition, taking into account:

- the emission factor for the fuel used before the fuel change;
- the climate correction coefficient.

The improvement in energy efficiency and the use of cleaner production were taken into account by using only output and energy consumption data. The production analysis for each year differs as regards both quality and raw materials and fuel used. Each individual production process has to be studied in order to establish the methodology that can be used for determining the impact of cleaner production and energy efficiency measures on GHG emissions in the production processes.

Reducing or increasing GHG emissions was also linked to changes in boiler house efficiency or the efficiency coefficient; however, its impact on the amount of heat produced in boiler house was currently taken into account only in individual cases, when operators supply sufficiently detailed information.

Climatic conditions were taken into account in recalculation using the climate correction coefficient. Using this coefficient makes it possible to determine the amount of GHG emissions if the number of degree-days matched the number of degree-days in the base year. When performing the recalculation the climate correction equation was used.

$$\Delta CO_2 = \left(k_{CO_2} - 1\right) \cdot CO_{2\,basis\ year} \qquad (3)$$

where

ΔCO_2 - reduction of GHG emissions, t CO_2/year;

k_{CO_2} - climate correction coefficient, from Table 1;

$CO_{2basisyear}$ - GHG emissions in base year, t CO_2/year.

GHG emissions before the project to reduce GHG emissions were calculated as follows:

$$CO_2 = CO_{2_{basis\ year}} + \Delta CO_2 \qquad (4)$$

Table 1

Values of climate correction coefficient

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
k_{CO_2}	0.971	0.976	1.029	0.906	1.00	0.992	1.076	1.133	1.022	1.047

Identification and assessment of energy efficiency measures

On the basis of the plan for introducing energy efficiency measures in buildings prepared by the Ministry of Economy, Latvian energy installations have the potential to reduce CO_2 emissions. Introducing energy efficiency measures in buildings would reduce energy consumption and energy demand from boiler houses or cogeneration plants.

In the allocation of allowances only the potential reduction of GHG emissions from energy installations of district heating systems is taken into account. On the basis of expert calculations a model of potential reduction of GHG emissions for energy installations supplying heat to households and the public sector is offered. The following reductions in GHG emissions are included in the model:

- in 2005 a 1% reduction compared with the basic scenario;
- in 2006 a 3% reduction compared with the basic scenario;
- in 2007 a 5% reduction compared with the basic scenario.

It has been estimated that the potential for reducing CO_2 emissions from energy installations which together making up an allowance totalling 206733.

The potential to decrease CO_2 emissions in industrial enterprises operating is not assessed for two reasons:

- ✓ industrial plants which are participating in emission trading scheme decreased production level dramatically during period 1992 … 1998 (when Latvia regain independence);
- ✓ there is no harmonised EU standard determining how much energy may be consumed per individual production unit.

Conclusions

1. National Allocation Plan of Latvia is based on bottom up approach of modelling of quantity of allowances for each installation.
2. Number of participants in emission trading scheme reached 96, which includes 72 mandatory installations and 24 voluntary installations. Human factor plays significant role.
3. Methodology is worked out and used for estimation of measures of reduction of GHG emission in boiler houses before basic year (as early action). Method will be used for modelling of reduction of GHG emissions during first period of emission trading in 2005 ... 2007.
4. It has been estimated that the potential for reducing CO_2 emissions from energy installations which deliver the heat they produce to the final consumer is 1% in 2005 (compared with the base year), 2% in 2006 (compared with 2005) and 2% in 2007 (compared with 2006), together making up 206 733 allowances.

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Plenary session
Cross cutting energy efficiency measures

THE CONTRIBUTION OF ELECTRO-TECHNOLOGIES TO ENERGY EFFICIENCY

Paul Baudry, Marie-Ann Evans
UIE (International Union for Electricity Applications)

The contribution of electro-technologies to energy efficiency

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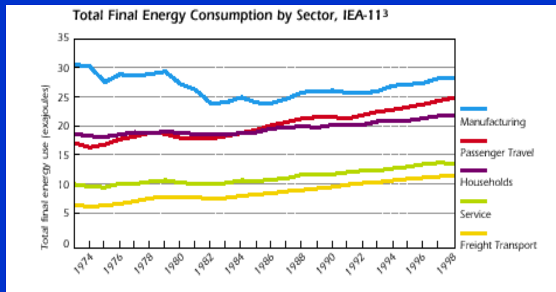
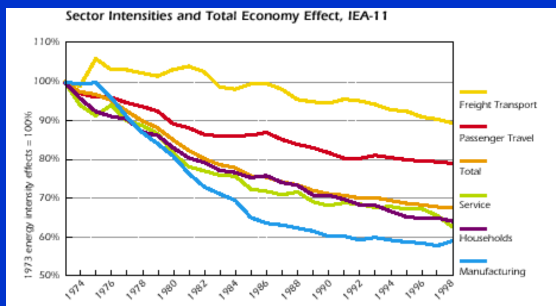
Conference on Energy Efficiency in IPPC installations – Vienna 21-22 October 2004

Outline

- Electricity and energy consumption
- The influence of energy accounting system
- Efficient electro-technologies in industry
- Conclusion

Global Trends in Energy use : 1970-2000



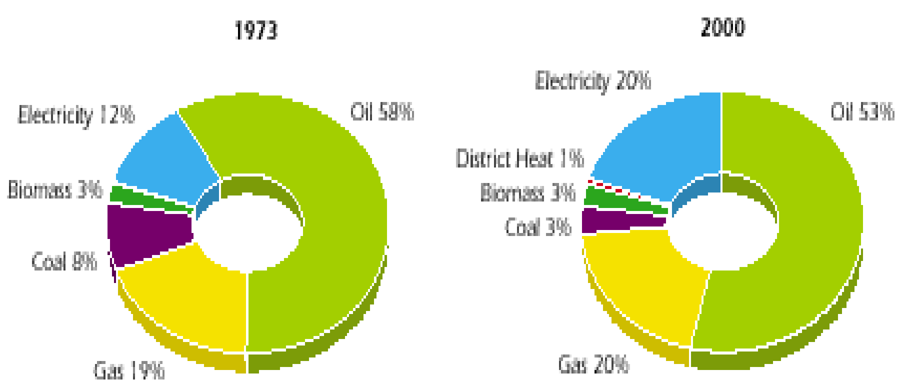


The sector of manufacturing (industry) shows the highest energy intensity decrease

Source : 30 years of energy use in IEA countries

Global Trends in Energy use

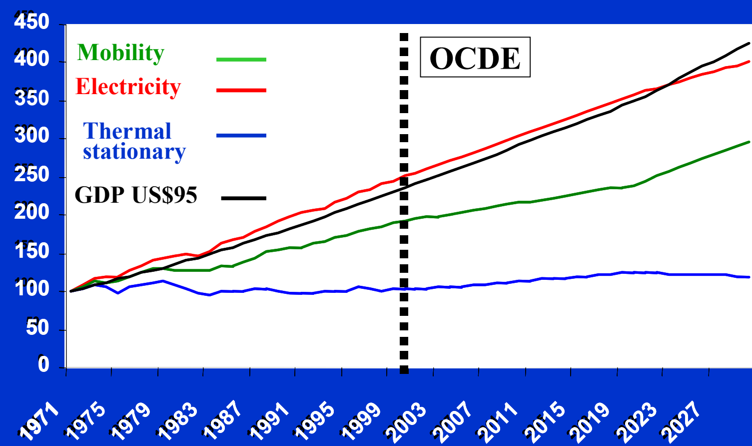
Final energy consumption by energy sources



Source : 30 years of energy use in IEA countries

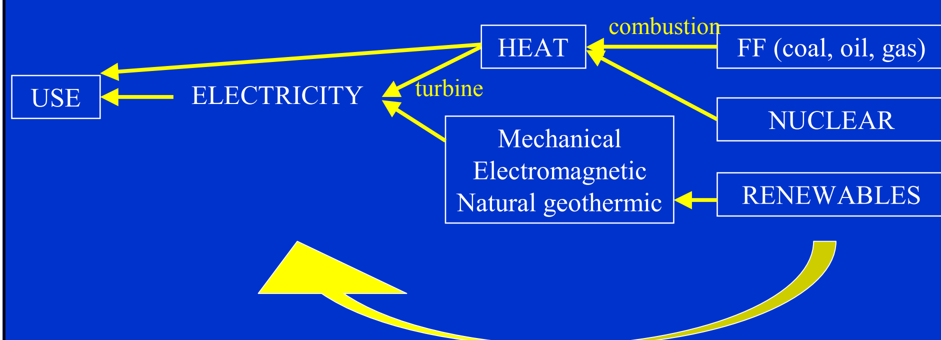
Energy efficiency and electricity

electricity use follows the GDP



Energy accounting system

primary to final energy

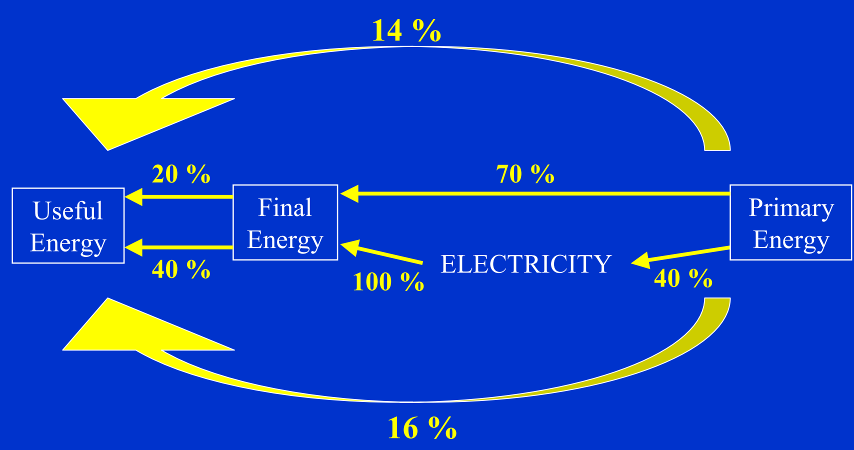


Coefficient of electricity generation

EU Average : 40 % or 1/2,5

Energy accounting system

primary to end-use energy



7

Energy Efficiency through Electro-technologies in various industrial sectors

Sector	Established Techniques	Emerging Techniques
Food industry	- MVC (liquid concentration) - Membranes (separation) - Electric Tubular Heat Exchanger - Heat Pump (heat and cold)	- High Electric Pulse Fields - High Pressure - Ohmic Heating
Chemical industry	- Motors for basic chemicals (v.s. turboengines) - heating in small processes (resitances and induction) - Electric Tubular Heat Exchanger	- Membranes in refineries and - Electrosynthsis - Ohmic heating - Immersion heater
Metals	-Electric Arc Furnace (steelmaking) - Induction in foundry - Resistance ovens (Thermal treatments) - Heat pumps	- MVC for liquid effluents - Recycling with arc furnace - Vacuum furnace
Waste management industry	- Electrofilters - MVC - Heat pump (drying)	- Cold plasmas for VOC treatment - induction on activated carbon for VOC treatment - MVC - Membranes - Arc furnace for vitrification

8

Energy Efficiency through Electro-technologies

Technology	Consumption – original plant (GWh)	Consumption – replacement plant (GWh)	Compared utilisation efficiency
Membranes	385	35	10-12
MVR + Heat Pumps	3.220	460	6-8
Induction	6.750	2.700	2-3
µW + HF + UV	585	260	2-2,5
IR	725	415	1,5-2
Motors	2.465	1.700	1,3-1,6
Resistance	11.640	9.700	1,1-1,3
TOTAL	25.770	15.270	1,1-12

Energy Efficiency through Electro-technologies
Steel industry

	Fossil Energy route	Electric route
Technology	Blast furnace	Electric Arc Furnace
Raw materials	Iron ore	« Scraps » (+ DRI + pig iron)
Quality	High	Depends on scraps quality
Investment cost	High	Much lower
Flexibility	Low	High
CO2 emission	2 t_{CO2}/t_{steel}	0.1 t $_{CO2}/t_{steel}$

Energy Efficiency through electro-technologies

Various energy system solutions for the same end use

Energy source	Same end-use demand (MWh)		Conversion used
Electricity from grid + Heat from fossil fuel	Electricity (light, motors) Heat (process)	100 100	1 kWh th = 0,086 tep 1 kWh e = 0,086 / 40% (electricity generation) / 90% (grid loss) CED = 23,9 + 8,6 = 32,5 tep
CHP from gas (non seasonal)	Electricity (light, motors) Heat (process)	100 100	1 kWh e = 0,086 / 66% (average generation efficiency by CHP) CED = 13 + 13 = 26 tep
Electricity from grid > 90% Fossil mix	Electricity (light, motors) Efficient electric process	100 <50	1 kWh e = 0,086 / 40% (electricity generation) / 90%(grid loss) CED = 23,9 + 11,9 = <35,8 tep
Electricity from grid Renewable / NFF	Electricity (light, motors) Efficient electric process	100 <50	1 kWh e = 0,086 / > 100% (pointless, NFF) / 90% (grid loss) CED = 9,5 + 4,8 = <14,3 tep
Electricity from grid current mix	Electricity (light, motors) Efficient electric technique	100 25	1 kWh e = 0,086 / 52% (electricity generation) / 90% (grid loss) CED = 18,4 + 4,6 = 23 tep

Conclusion

- Electricity is a secondary but **flexible energy**. Industrial process need this flexibility to increase **productivity** and **quality**

- **Electricity and electro-technologies** can contribute significantly to **energy efficiency**

- Final to primary **conversion factor** and **CO2 emissions** depend strongly on power generation systems, thus on **local energy mix**

- The whole energetic system has to be assessed from **raw energy product** to **end-use** by an **LCA** approach

Plenary session
Cross-cutting energy efficiency measures

ENERGY EFFICIENCY PROGRAMS IN INDUSTRIAL COMPANIES

Andreas Kollegger
Allplan GmbH
Schwindgasse 10, 1040 Vienna, Austria
Phone:+43/1/5053707-53; E-mail: andreas.kollegger@allplan.at

ENERGY EFFICIENCY PROGRAMS IN INDUSTRIAL COMPANIES

***Andreas Kollegger**, Allplan GmbH*

1 Introduction

Energy is one of the major factors in the energy intensive industry and currently gains even more importance because of the necessity of CO2 emission reduction due to the Kyoto Protocol and the European Emissions Trading Scheme. Therefore more and more companies start thinking of possibilities in saving emissions and energy in their installations.

The intention of an “Energy Efficiency Program” is to increase the energy efficiency in enterprises and to decrease energy consumption, energy costs and environmental pollution.

Allplan has developed a standardised method, which can be applied to each industrial company, independent of the industrial sector and the goods produced. This method (AEEP=Allplan Energy Efficiency Program) has been successfully applied in more than 50 companies (paper, chemical, steel, food, car, cement and other industries) in nine different countries (Austria, Finland, Netherlands, Germany, Switzerland, Czech Republic, Hungary, Slovenia, Romania) in the past years.

In the following, the procedure of an AEEP will be outlined shortly and a few examples of actual measures implemented in the chemical industry will be described.

2 Procedure

For carrying out an efficiency analysis it is important to do this in an ordered way beginning with an overview and concentrating only on relevant details. Otherwise relatively small, unimportant but time-consuming parts would be analysed or some of the significant saving potentials could be overlooked.

In the following, the usual procedure for the implementation of an efficiency analysis is outlined and described.

- Description of the actual situation
- Technology check according to the state of the art
- Measurement, Data Acquisition
- Analysis
- Calculations
- Saving Potential
- Calculation of Savings
- Cost Assessment for Energy Saving Measures
- Best technical and economic solution

Description of the Actual Situation

The analysis begins with an energetic overview of the two principal areas heat and electricity.

The field heat includes the boiler house, steam condensate and hot water systems, process heat consumers, room heat consumers and waste heat.

The electricity field includes the generation of electricity (steam, water and gas turbine), transformers, all kinds of electric drives (such as pumps, fans, drive motors and drives from special production devices), compressors, lighting and cooling.

For all subsystems and (larger) equipment units in these areas relevant technical data (producer, type of equipment, year of manufacture, operating mode…) is collected.

Technology Check according to the State of the Art

The obtained data of the important equipment units is compared to the most efficient, state of the art equipment. For that purpose the comparison with the theoretical lowest consumption and a bench marking within the industry sector can be useful.

In any case comprehensive knowledge of procedures and equipment has to be acquired for this task, therefore close contact with the different manufactures is extremely important.

Measurement Data Acquisition

To begin with calculations and to get consistent results, the acquisition of tenable operating data is a crucial point. The two ways of acquiring this data are:

- the use of existing data measured by the operator himself
- own measurements

Data Consistency Check and Analysis

A desirable way for a data consistency check and the determination of bad data is carrying out both ways of data acquisition (acc. to 2.3) and comparing existing operator data with own measurements. This means more expenses for data acquisition, but guarantees stable results and less surprises in the further course of action.

Calculations and Flow Determination

With consistent data, calculations on mass and energy (exergy) flows can be carried out to determine the flow paths throughout the plant. The optimisation starts with the equipment parts handling the largest energy flows, because there even small relative improvements result in significant absolute energy (and cost) savings.

Saving Potential

As mentioned above, the optimisation analysis should reasonably start with the biggest energy flows. These energy flows have to be followed through the plant to find the “bottleneck(s)” where a lot of energy is lost.

The next step is to develop a technical solution improve none optimal process equipment and/or procedures.

The optimisation solutions can either be the replacement of parts of the equipment or the improvement of the process procedures respectively combining both of these possibilities. Especially for this step, extensive know-how is very important because each situation requires its own “tailor-made” optimisation and a suitable adoption.

Calculation of Savings

Resulting from the optimisation potential analysis the potential savings in energy and cost can be calculated. For this, it is necessary to know the operational mode during normal operation, down times, maintenance and services during the year. With these factors and the corresponding costs for the different utilities the yearly savings are calculated.

Cost Assessment for Energy Saving Measures

In this step, the costs for the technical solutions have to be determined. Additionally to the equipment costs, the costs for labour and capital have to be considered. To get a reasonable solution, equipment manufacturers and assemblers have to be involved.

Best Technical and Economic Solution

The costs for the technical optimisation solutions are placed opposite to the yearly savings and the ROI (return on investment) or similar financial ratios are determined. Only solutions which are both technically and economically feasible have a chance for implementation.

Additionally, some kind of life cycle assessment can be performed, because the cost consideration does not always show the whole picture.

3 Selected Examples

Example: Sankey Diagram

The following figure shows an example for a Sankey Diagram. This is a graphical representation of the different energy flows within a production plant.

Figure 1: Example for a Sankey Diagramm

Data Basis for these figures can be:

- own measurements
- company data
- clients measurements
- own calculations

Example: Optimisation of Boilers / Use of Waste Heat of Boiler

Boilers are the “bottlenecks” in energy systems of production plants. A high share of the total amount of used energy in the plants are processed and transformed in boilers. So efficiency increases are very effective (in terms of saved energy and costs). Starting with an incineration calculation and the calculation of the boiler efficiency and boiler losses, the following optimisation can be achieved:

- Avoidance of radiation losses
- Reduction of CO in the flue gas
- Decrease of flue gas temperature, flue gas condensation

In some cases the flue gas temperature of a boiler is considerably high. Due to that fact, a lot of useful energy is lost through the stack. By installing a heat exchanger in the flue gas flow, part of this energy can be recovered and used in other appropriate parts of the production.

The following figure shows a simple flow schemes of different implemented heat recovery systems. In both situations, part of the heat in the flue gas is used to preheat water, which is used in the adjacent production plant and/or as washwater.

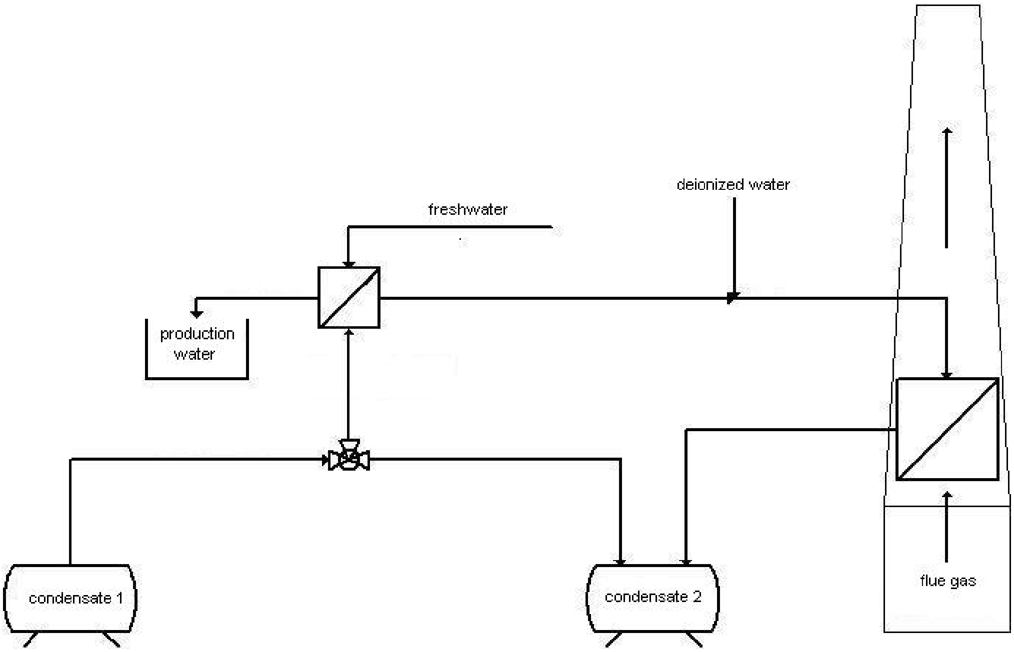


Figure 2: Example for a heat recovery system

The following figure shows the dependency of the boiler efficiency from the flue gas temperature. Below the dew point of the flue gas, a great amount of heat can be recovered, because the water vapour in the flue gas condenses and due to that, the latent heat can be recovered additionally.

For “low quality” fuels (coal, heavy fuel oil with high sulphur content) problems arise, when cooling the flue gas below the dew point. Acids (mainly sulphuric acid) condense and corrode the materials in contact with the flue gas resulting in equipment failure. For these kinds of fuel, the flue gases can only be cooled down to a temperature well above the dew point (the dew point varies and depends on the composition of the fuel gas) and this way only the sensible heat can be partly recovered.

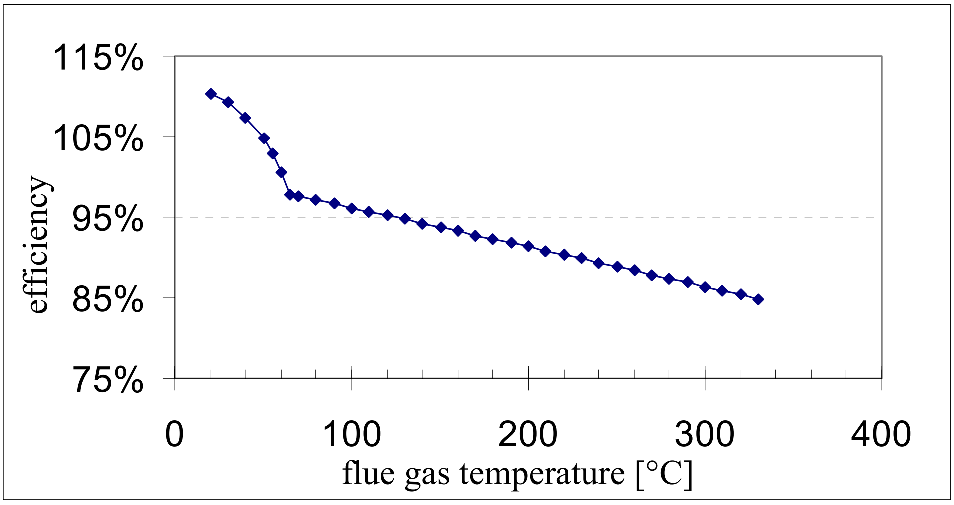


Figure 3: Example for a heat recovery system 2

Example: Use of Waste Heat of a Production Process

Not only waste heat of boilers can be utilised, also the waste heat of production processes can be used purposefully. The following figure shows the utilisation of the waste heat of a brick cooling system for a central room heating system. Every single optimisation system has its own difficult parts. In this case, the wastegas has an extremely high dust content and the heat exchanger had to be designed especially for that purpose.

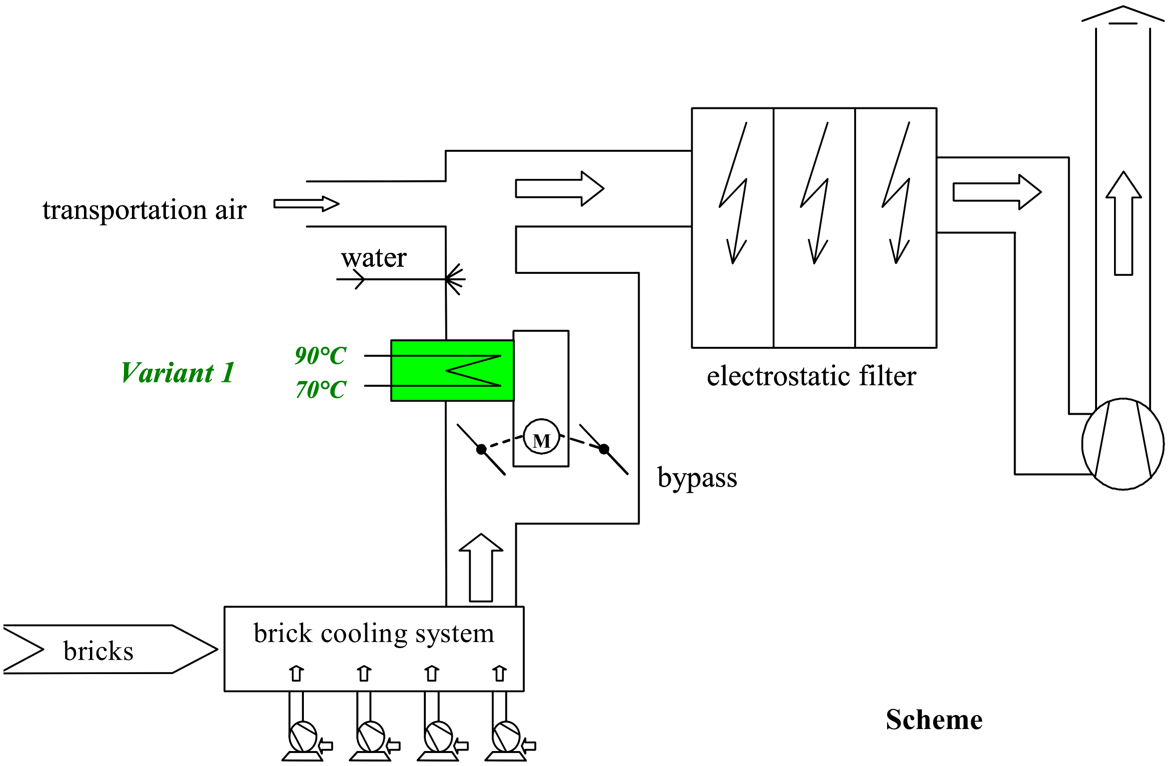


Figure 4: Example for a production heat recovery system

Example: Change in Control Systems

In many cases highly sophisticated control systems are installed in all sorts of production equipment units (e.g. pumps, fans, various transport equipment), but their settings do not correspond with the actual demand of the production plant due to adaptations of different parts of the plant. By simply adapting the existing control system to the actual demand, in some cases a lot of energy can be saved with almost no investment requirement.

In other cases by retrofitting simple control units to production equipment units, their modes of operation can be adapted to the actual demand of the production plant and the excess energy (because of the currently too high flows, to “stay on the safe side”) can be saved.

Because almost every control unit is different from the others, no general rule can be applied here. Every system has to be analysed by its own and the optimisation often can simply be made by a simple trial and error procedure. The following figure shows the characteristic diagram of different control systems for a fluid transportation system with a centrifugal pump. The dependency on the relative power consumption from the different control systems is shown. Within certain ranges a control system with a frequency converter can save up to 50% of the energy needed compared to a throttle controlled system.

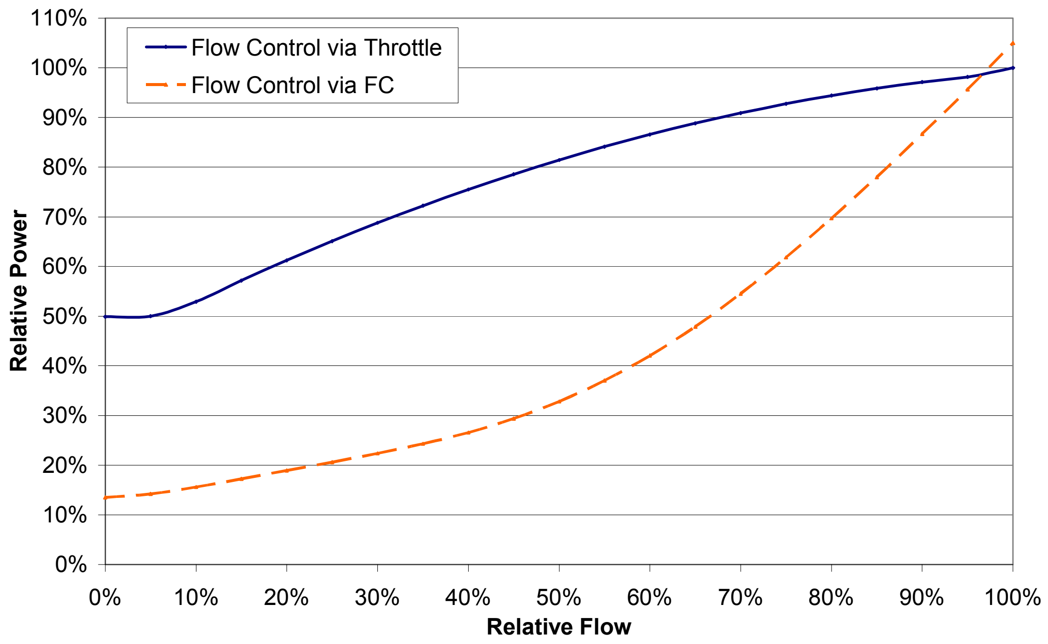


Figure 5: Example for characteristic diagrams of control systems

Example: Optimisation of Compressed Air

Usually, most of the companies see a compressed air system in some way as a "black box" – you plug it into the electricity grid and on the other side, pressurized air comes out. So very often, there is a huge electrical saving potential for compressed air systems.

The various optimisation opportunities are:

- Adaptation of control units for
  - Optimising the pressure levels
  - Optimising the load to idle run ratio, reducing the idle run time
- Upgrade or change of control units
- Switch from conventional compressors to aggregates with frequency converters
- Exploitation of the inevitable waste heat
- Assessment of distribution losses and repair of the distribution system
- Adaptation of the distribution pipes to optimum pipe diameters

The main objective of an optimisation is to adapt the pressurized air supply to the actual demand of the production plant, to reduce the run time, especially the idle run time to the lowest possible level.

For that the calculation of the specific work of the compressors is the starting point. The results of additional measurements to determine the load and the idle run time respectively the stop time are shown in the following figure.

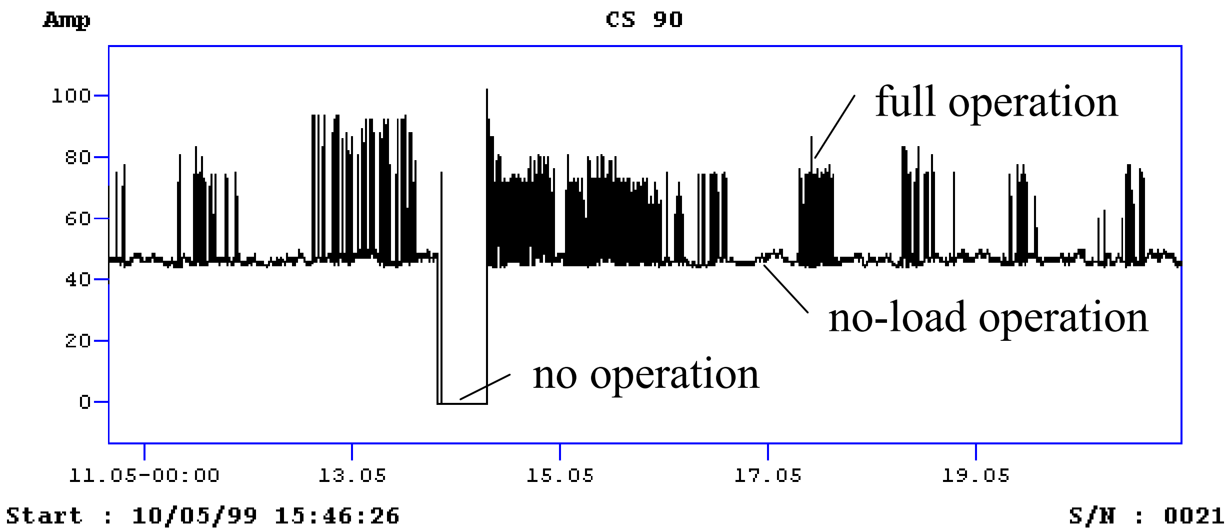


Figure 6: Example for the determination of the load and the idle run time respectively the stop time of a compressor

The result of this measurement for the above mentioned optimisation opportunities can be obtained and implemented.

The possible saving potential for repairing leakages in the distribution system is outlined in the next table. It can easily be seen, that this simple task makes good economic sense at all times.

Leakage Diameter	Compressed Air Requirement	Power Requirement	Additional Costs (8.760 hours)
[mm]	[m³/min]	[kW]	[EUR/a]
1	0,084	0,54	166
2	0,337	2,18	668
4	1,348	8,71	2.670
6	3,032	19,59	6.006

Table 1: Costs resulting from leakages in a compressed air distribution system (8 bar gauge)

Example: Illumination

Similar to the compressed air system, the illumination system is no focal point in a production plant and therefore high saving potential can sometimes be found.

The following issues are important for an illumination system:

- Building structure
- User behaviour
- Illumination technology
- Connecting capacity
- Adapting of illumination structure to user structure
- Control equipment
- Modern illumination systems

By analysing these issues and adapting them to the actual requirements only the inevitable amount of electricity has to be used for lighting purposes. The following figure shows an example for an optimisation approach for illumination systems (modern illumination system).

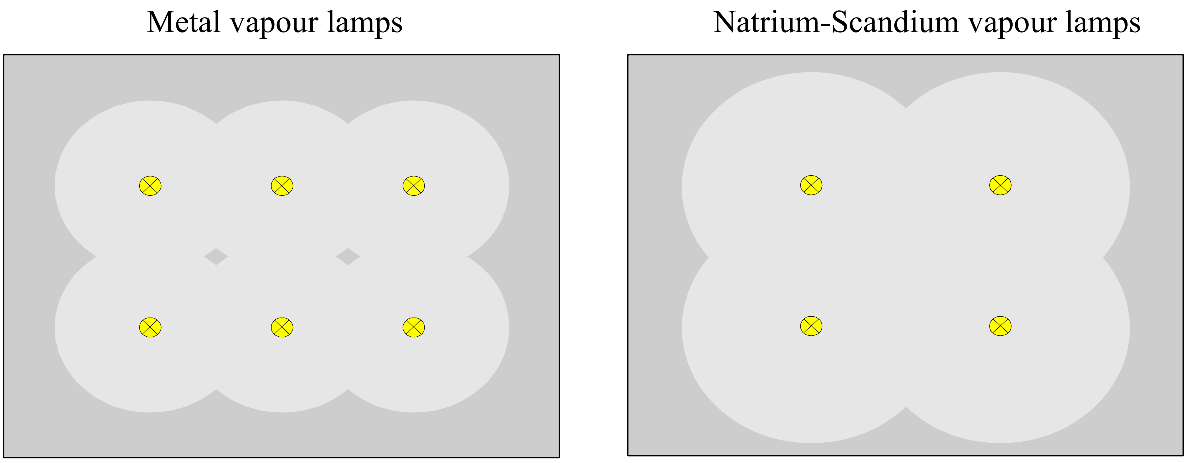


Figure 7: Example for optimisation of an illumination system - Improvement of the lamp technology

Example: "Free Cooling" of Tanks

This example shows the supplementary addition of a "free cooling" unit to an existing conventional chiller system. The free cooling unit amounts to a considerable part of the total needed cooling load by only consuming a fraction of the energy, which would be needed in the conventional chiller unit. At appropriate outside and production conditions, the conventional chiller system can be fully switched off and the system works solely on the free cooling unit. This way a huge amount of electric energy can be saved during one year.

The reliability of the total system is guaranteed, because the cooling system can be operated as before and additionally to the saved electric energy, supplementary safety follows from the installation of a second cooling system.

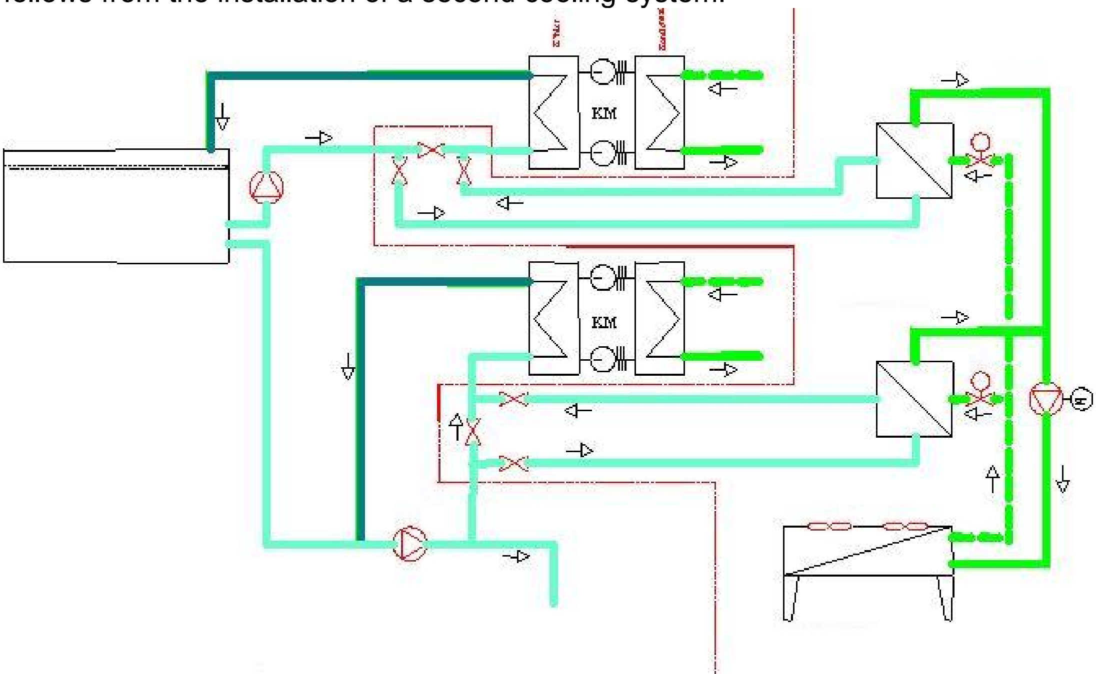


Figure 8: Example for supplementary addition of a "free cooling" unit to an existing conventional chiller system

Other Saving Potentials

- Co-generation at the premises
- Potentials for district heating
- Own electricity generation
- Long-term energy management
- Optimisation of transformers
- Peak load management

4 The Results

The basis for the following charts and numbers derive from 28 Allplan Energy Efficieny Programs carried out in Austrian production plants. This should impressively underline the possible energy and cost saving potential in production plants in almost all (energy intensive) sectors of the industry. All included measures have a pay back period in less than 3 years!

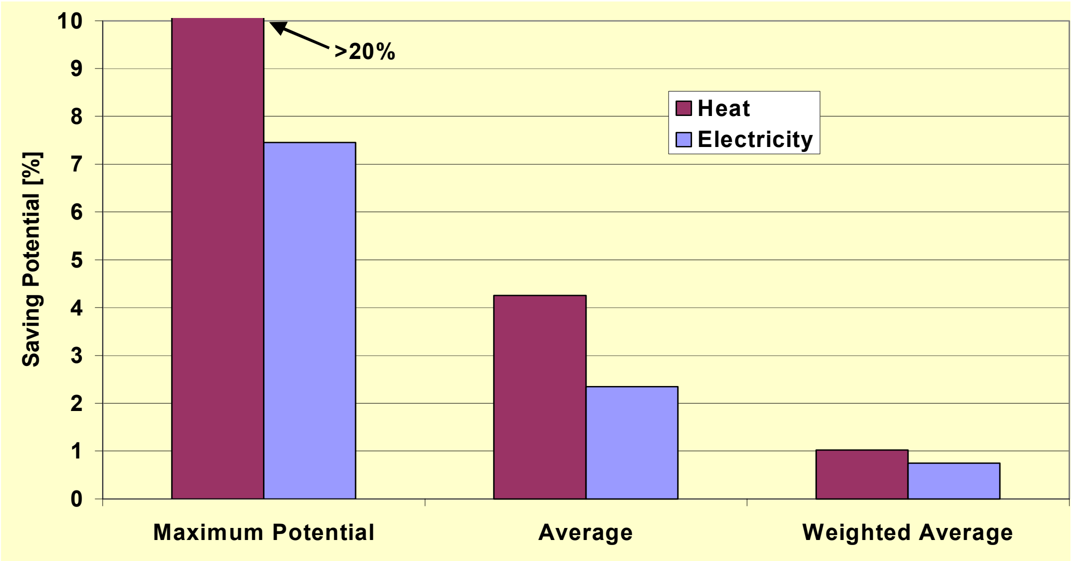


Figure 9: Heat and Electricity Saving Potential found

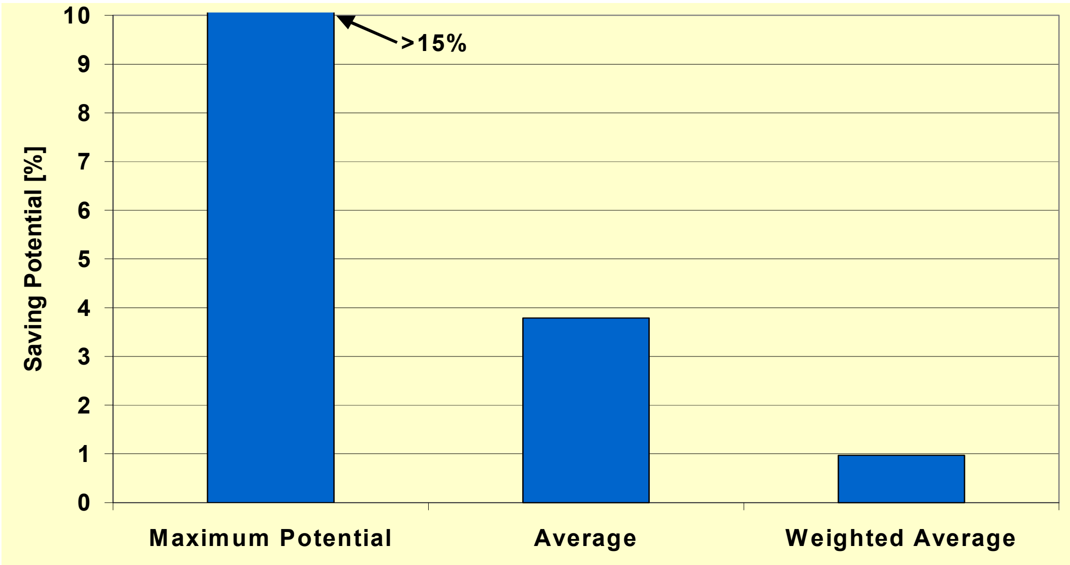


Figure 10: Entire Saving Potential found

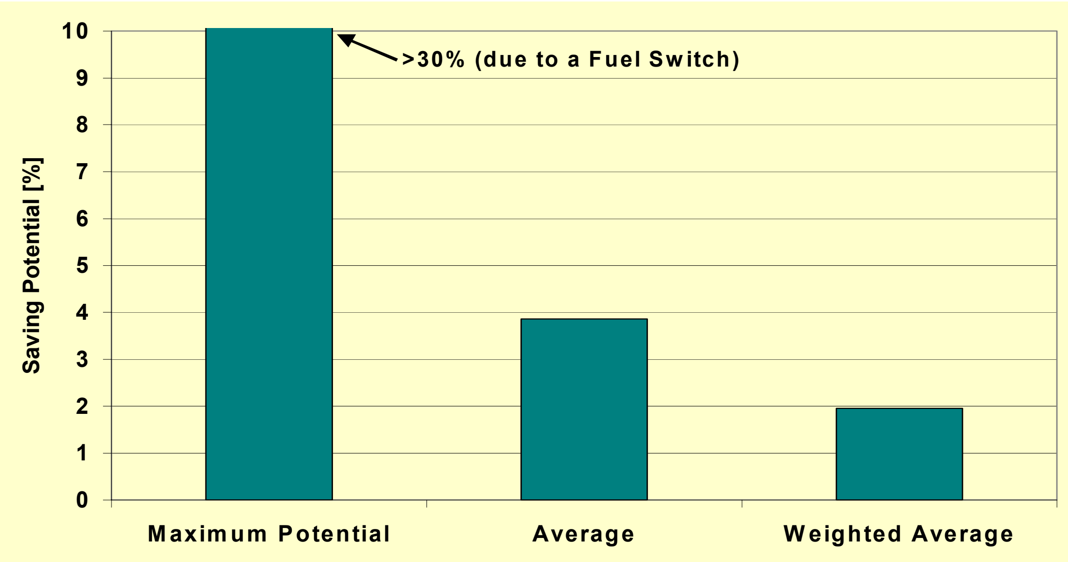


Figure 11: CO2 Emission Saving Potential found

Saved Electricity:	**> 6.000.000 MWh/a**
Saved Heat Energy:	**> 25.000.000 MWh/a**
Saved Energy Costs:	**> 7.000.000 €/a**
Saved CO_2 Emissions:	**> 50.000 tCO_2/a**

Table 2: Savings due to 28 AEEP´s in Austrian companies (all measures with pay back periods < 3 years)

In 28 Austrian industrial production plants over 6 Mill. MWh electric energy and over 25 Mill. MWh heat energy are saved after the implementation of suggested energy efficiency measures every year. This results in a reduction of over 7 Mill. € of energy costs every year and every measure has a pay back period of less than 3 years, sometimes almost zero.

Regarding the greenhouse gas emissions, over 50.000 t of CO2 can directly be saved in the production plants due to reduced fossil fuel consumption. Additional CO2 emissions are indirectly saved due to reduced electric energy consumption in various fossil fuel fired power plants. This amount depends on the "generation mix" of the grid electricity.

As shown above, due to various energy efficiency measures huge amounts of energy and energy costs can be saved, sometimes with little or almost no investment requirements.

Plenary session
Assessment of energy reduction potential in industry

THE ENERGY EFFICIENCY BENCHMARKING SYSTEM AND BAT

Hubert van den Bergh
Verificatiebureau Benchmarking
E-Mail: Hubert.Van.den.Bergh@vbbv.be

The Energy Efficiency Benchmarking System and BAT

Hubert Van den Bergh

A system which is running in the Netherlands and in Flanders (I)

→ because of the tight Kyoto burden sharing

in Flanders large installations started up between the Kyoto reference year 1990 and the Kyoto protocol year 1997.

→ the policy not to obstruct growth of companies

companies with a good prospect for future are those who grow.

A system which is running in the Netherlands and in Flanders (II)

→ government did not want to impose absolute caps on energy consumption or greenhouse gas emissions…

→ … but expects optimised energy efficiency of production installations, in a quantified way

→ standards must be set; the benchmarking system is the way to these BAT-standards

General outline of Benchmarking

→ the company makes a split up of its facilities into benchmarkable installations

→ for every installation a study is performed to compare energy efficiency with similar installations in the world

→ for energy intensive installations it is assumed that the best installations are BAT

→ the BAT-standard allows a certain margin

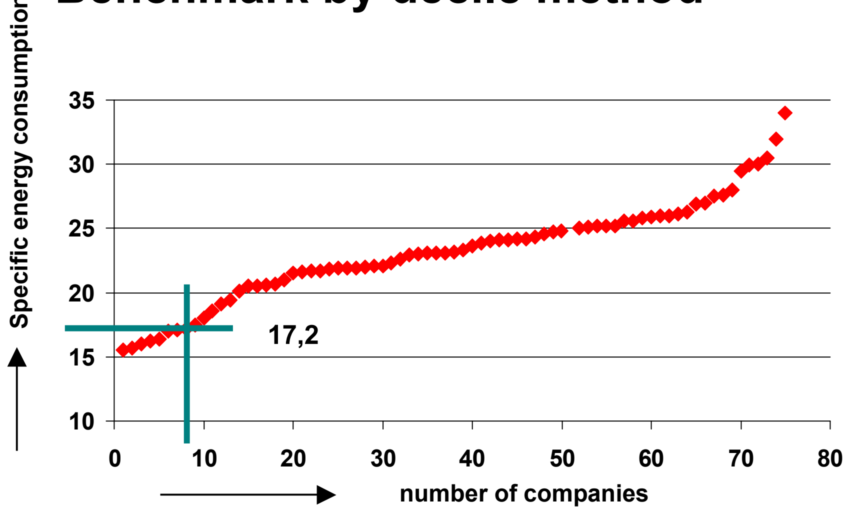
→ the covenant requires to attain the standard

Benchmarking methods

The benchmarking methods, in order of application priority are:

1) Full benchmarking of all installations in the world; the decile point gives the standard (Decile method)
   - may require a lot of data
   - co-operation of all important world actors is necessary
   - result is very acceptable, irrespective of the consumption span
   - irregularities are rare

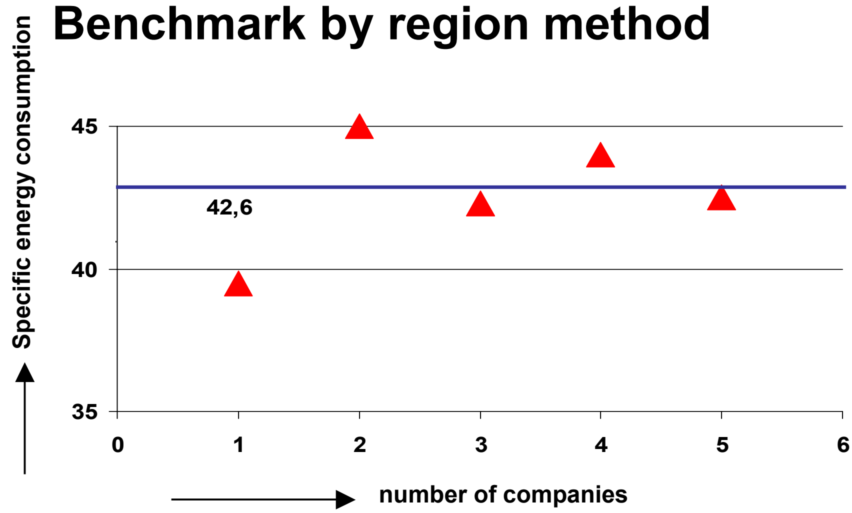
Benchmark by decile method



Benchmarking methods

2) Benchmarking in the best region in the world; the average consumption of the installations in the best region gives the standard (Region method)
   - first a best region must be defined
   - that region must be acceptable as BAT-standard for the world
   - definition problems about number of regions and number of companies in the region
   - difficult method
   - method may be desirable to limit the number of installations of the full benchmark

Benchmark by region method

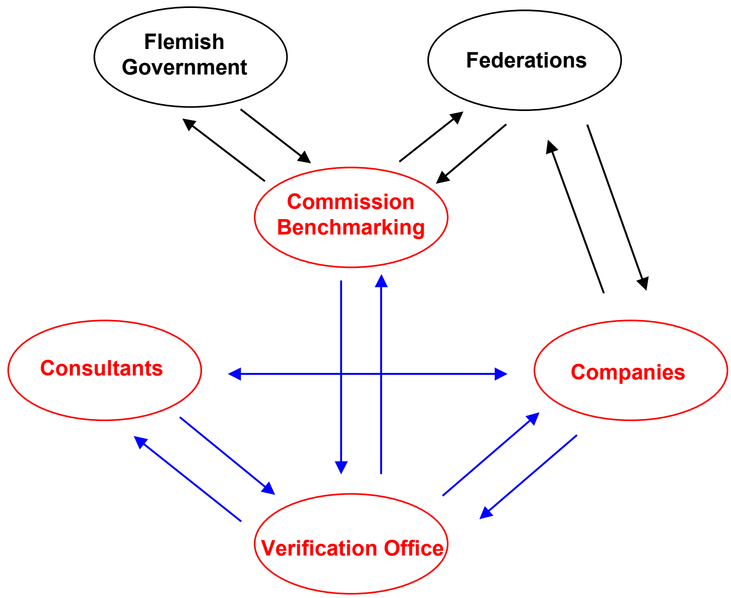


Benchmarking methods

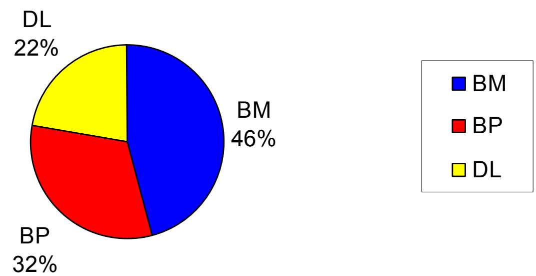
3) Best Practice: the world best installation has to be found and to be assessed; standard = world best + 10%
   - good feasibility in terms of investigation work
   - proof of "world best" is not evident, but more feasible than for the region method
   - 10% may be too tolerant as margin

Benchmarking methods

4) Auditing: if other methods fail, the installation must be thoroughly audited – standard = own installation after execution of all economically efficient measures (I.R.R. > 15%)
   - this method gives little handhold
   - results are often disputed



Study type based on energy consumption



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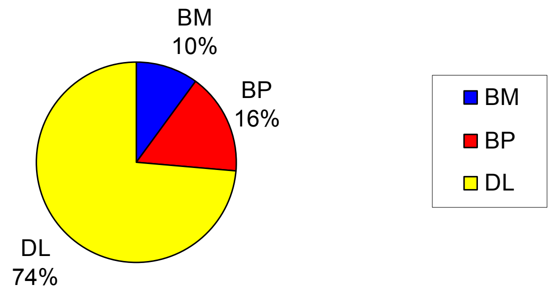
Study type based on number of processes



State of the art of the Covenant

In Flanders:

- Covenant approved by government on 29.11.2002 for companies > 0,5 PJ, later also companies which must participate in system of emission rights (T.E.R.)
- 176 companies participate in the Covenant
- commitment to achieve BAT, to be specified in an energy plan
- energy plans submitted 30.06.2004, by all T.E.R.-companies
- all energy plans to be verified by 15.09.2004

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- results of the energy plans in evaluation, to be released by the end of the year
- T.E.R. allocation based on energy plans
- monitoring every year, by 1st April
- cycle to be repeated every 4 years

In the Netherlands:

- covenant signed 06.07.1999
- second cycle starting now

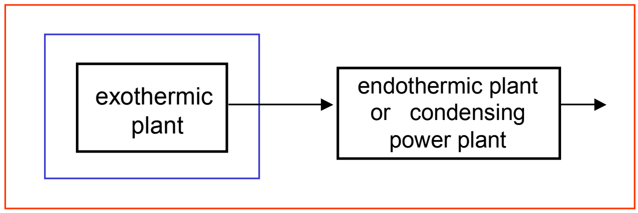
Is Benchmarking an easy way to find BAT-standards?

Unfortunately not…

every installation has its own difficulties!

Benchmarking/BAT practical situations

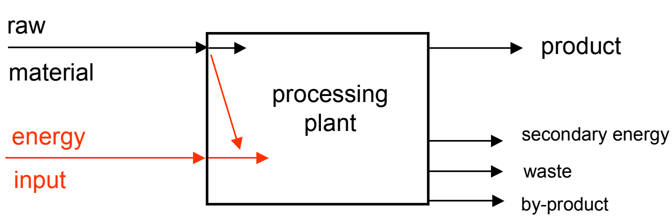
1) Boundary Limits



The choice of limits may lead to a very different result and ranking.

Benchmarking/BAT practical situations

2) Raw materials and fuels

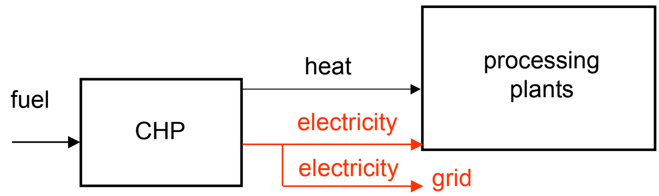


Which flows to be accounted for?

Which subtractions in the covenant?

Benchmarking/BAT practical situations

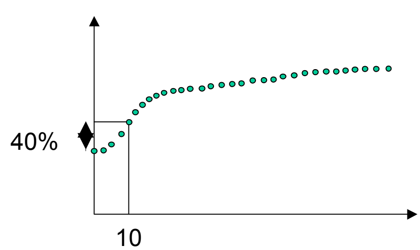
3) Combined Heat and Power



How much fuel to be allocated to the processing plants?

Benchmarking/BAT practical situations

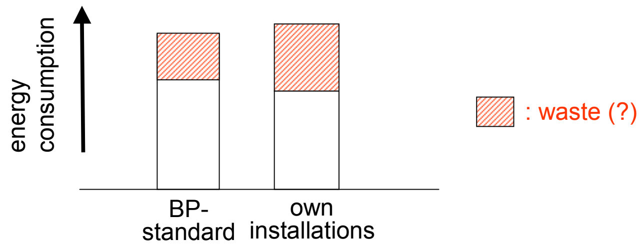
4) Irregular Benchmarking curves



Can one accept such a decile point?

Benchmarking/BAT practical situations

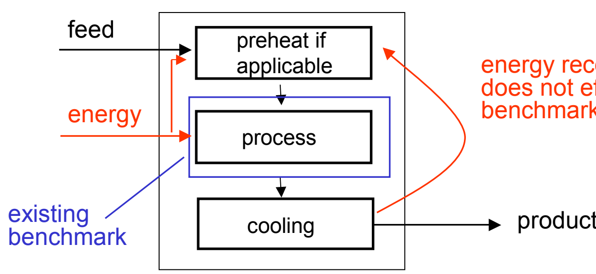
5) Waste fuels should not be accounted for



What is to be considered as unbenchmarkable waste?

Benchmarking / BAT practical situations

6) Existing benchmarks



How to deal with existing benchmarks if they do not really fit the covenant expectations?

WANTED: INTERNATIONALISATION

→ for cost reduction of new benchmarks

→ for better participation of competitors

→ for quality improvement: level playing field

INDISPENSIBLE

→ as soon as the burdens become more tight

Plenary session
Assessment of energy reduction potential in industry

POTENTIAL BATS IN ENERGY EFFICIENCY AND RELATED LEGAL INSTRUMENTS IN THE CZECH REPUBLIC

Monika Pribylova, Vladimira Henelova
ENVIROS
Petr Honskus
SPG Group

POTENTIAL BATS IN ENERGY EFFICINCY AND RELATED LEGAL INSTRUMENTS IN THE CZECH REPUBLIC

Vladimira Henelova, Monika Pribylova, *ENVIROS*

Petr Honskus*, SPG Group*

IPPC energy efficiency requirements

For many years horizontal integration of energy efficiency into all politics and programmes has been promoted, in practice, though, integration of energy efficiency requirements and environmental legal instruments has not been fully accomplished and energy efficiency requirements still make difficulties to many industries and – with regard to IPPC – to both the regulator and the subjected installations and sites.

In the IPPC Directive the requirement has been stated twice – first BATs can only be those techniques leading to efficient use of energy and then the Article 3 stipulates the requirement on the national Authorities that energy is to be used efficiently.

The company should be able to demonstrate that it uses energy efficiently or it intends to do so through gradual improvement in the future. (The installation should be operated in such a way that energy is used efficiently. All possible measures should be applied – mainly using the best available techniques – to avoid direct and indirect pollution.)

In order to be able to demonstrate energy efficiency, it is good to have some etalons, some benchmarks or indicators to do so.

Bottlenecks perceived by environmentalists

In „European Union Network for the Implementation and Enforcement of Environmental Law“ Final report on Energy Efficiency in Environmental Permits, key difficulties as to energy efficiency are listed:

1) The definition of energy efficiency

Defining energy efficiency in practice is considered to be very difficult because of the differences in the nature of the installations to which energy efficiency applies.

2) Binding permit conditions

In most cases it is not considered possible to set up enforceable conditions for energy efficiency in a permit for an individual installation. It is difficult to make a specific condition for energy usage,

3) Enforcement and supervision

As a clear definition of energy efficiency is not available, direct enforcement and supervision by environmental authorities is more difficult.

4) Publicity/confidentiality

Data on energy issues might be considered as sensitive.

5) Relations to emissions trading

Greenhouse gas emissions trading will affect the application of the IPPC directive. Until now there has not been a clear picture of how the links between emissions trading and IPPC permitting will work.

6) Voluntary systems versus permit

Also the interrelationship between the voluntary agreements and permit conditions is part of this problem. The targets of voluntary agreements and the means of permitting do not always coincide, for example, the requirement of continuous improvement is too vague as a permit condition.

7) Lack of information and expertise - Generally there is a lack of expertise and information on how to apply energy efficiency in the permit procedure.

We need benchmarks - do we have benchmarks?

Two years ago our company and several other partners from the EU submitted a proposal for SAVE programme in order to clarify energy efficiency requirements under IPPC – that time in pulp and paper industry. The proposal, developed in cooperation with CEPI and national Pulp and Paper Industries Association, was not selected with an explanation that in this field sufficient amount of work has already been made.

The project aimed at promotion of energy efficiency in industry and at developing an Energy Efficiency Guideline for Paper Industries in order to develop cost-effective strategies for increased energy productivity as a part of their environmental and enterprise policy enabling them to meet extended environmental and energy efficiency legal requirements. It was expected that the guideline would comprise energy benchmarks and cost-effective energy saving techniques incl. energy management and RES utilisation options. Information like the BREF document, Dutch LTA´s, CCLA´s in the UK, national data of Italy and outputs of audits performed at sites in CEECs were to be made use of in order to specify potential for reduction of energy demand and of emissions released (incl. CO_2 emissions).

In processes, BREFs describe unit consumption of energy and this figure can become the benchmark.

Energy, though, is not used only in installations itself, but also in buildings, auxiliary operations and equipment, in other processes or installations and it also is being lost. Is this energy also subjected to the law on IPPC?

Czech Law on Energy Management

In the Czech Republic Energy efficiency standards are laid down by a Law on Energy Management since 2000. The law, initiated by the Czech Energy Agency stipulates the following:

- Minimum energy efficiency standards for:
    - heat and electricity production,
    - electricity transmission and distribution
    - heat outdoor and indoor distribution
    - heat losses minimisation in buildings
    - requirements on thermal insulation qualities of buildings.

  (The standards apply for both and reconstructed boilers, distribution networks, CHP units, buildings, etc. and could be taken as **benchmarks** in the stated processes. The standards not only specify minimum efficiency in percentage, but criteria dealing with regulation, quality of insulation, water leakages, etc.)
- Compulsory and detailed energy audits for companies (and buildings) exceeding given threshold in energy consumption - the energy audit specifies organisational and investment measures that should be implemented in order to comply with the minimum energy efficiency requirements. It should specify in alternatives how to achieve in economic way higher energy efficiency and the required energy efficiency standards in a given company.

Energy audits are not by themselves sufficient. Despite the fact that the audit specifies what should be done to use energy more efficiently, the recommendations should be as far as possible also implemented; implemented in line with economic possibilities of the company.

Many energy audits are not well accepted by financial managers of companies. Why is it so? The data on the basis of which the energy audit calculated revenues from energy saving measures are rarely based on real and verifiable data – mostly the data are just calculated. The financial managers do not believe in figures that cannot be proven.

And – with regard to IPPC - it is difficult to specify energy consumption just in one installation itself if it is not metered. Therefore the definition of the installation scope is crucial for energy efficiency measures.

Energy audit is not sufficient – what else can be done? Company could make use of the energy audit and develop a plan on energy efficiency increase.

Are we able to benchmark and plan?

The main objective of the Directive on IPPC is prevention (in case of new installations and plants it means to keep to technical standards and laws given). Another objective is limitation of already existing pollution and companies should submit a plan on limitation their contribution to pollution.

Can we verify that an improvement has been made in energy efficiency? Can we verify it in case of changes in the product mix, volume of production changes, etc?

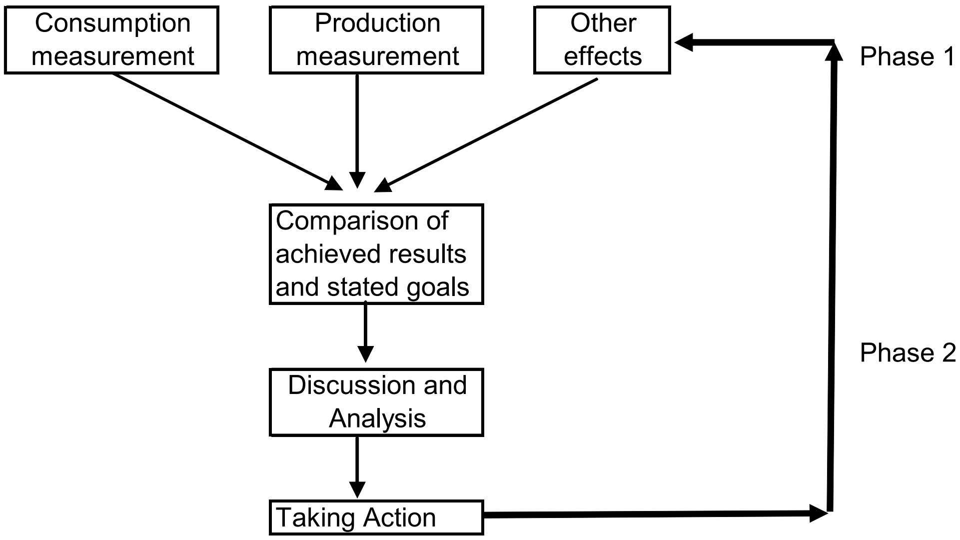
It is possible in case we install metering, monitoring, evaluation and targeting of energy consumption. We will have reliable data through a system called monitoring and targeting (M&T). We can make unit/relative data and target the consumption. We meter, monitor, analyse, propose improvement measures, monitor, analyse ….. In case we do have data (metered, repeated every week or month), we can benchmark our consumption. We can consider M&T system as BAT in energy management. Is energy management BAT in energy efficiency?

Is the system of data monitoring and analysing sufficient?

It is not and we need responsibility of those who manage the company – we need energy management system be introduced. Existence of a viable system of energy management could be one of the requirements of the regulator. The existence of a viable system of energy management enables the company to demonstrate that goals are being achieved and an improvement is taking place. Or the other way round, it can present well based arguments that the goals (or an improvement) cannot be achieved.

That is why other qualitative parameters are being required in the UK. What are the qualities of the system? Clearly set policy, responsibilities, monitoring, reporting, control.

How M&T works?



Further Steps in the Czech Republic

The Czech integrated permitting system was introduced in 2003 by the new Act on IPPC No. 76/2002 Coll. This Act requires in compliance with IPPC directive to set binding conditions for effective use of resources and energy in the integrated permit. The application form for integrated permit requests to fill detailed tables on:

- fuels and energy inputs,
- energy production,
- use of energy,
- specific energy consumption on products/activities,
- improvement measures in energy efficiency and
- comparison of the consumption of energy and energy efficiency with BAT.

Also companies have to submit the energy audit report as the annex to the application. The audit does not deal with just an installation and does not present any commitment. And what is needed under IPPC is clear demonstration of commitment.

In practice the following problems arise during setting the permit conditions related to energy efficiency:

- as the deadline for energy audits is the end of 2004, then there have been many operators, who do not have the audit ready when submitting the permit application; in such cases permitting authority sets the condition to submit the conclusions or suggested improvement measures from the energy audit when they are available.
- In case the energy audit is submitted with the application, conditions are often worded very generally e.g. “to carry out the measures as derived from energy audit in order to decrease the energy intensiveness for unit of production.” Such a condition is practically impossible to enforce and its practical implementation depends on the operator’s management and mix of business goals.
- In case the operators energy efficiency/consumption differs with proposed energy efficiency/consumption in the BREFs, the operator often argues by his special combination of technologies within the plant and the permitting officer is rarely competent to make technical discussion on this topic.

Permitting officers has no guidance on how to set enforceable energy efficiency conditions. Thus even if the legislation allows flexibility, it cannot be utilized due to missing linkage between energy management legislation and IPPC legislation, missing knowledge on how to set enforceable conditions related to long term energy efficiency improvements or how to link the conditions to other regulatory tools.

Considering the regulation more broadly, the following question arises. Does the regulator have any target or priority to be achieved in practice?

If concrete results are to be achieved, there has to be two levels – one for existing facilities and another for new facilities. Existing facilities can use the norms and standards as benchmarks for setting the gap between norms and real performance. Energy audit should say how much would cost to achieve such targets and what is economically feasible and what not. New facilities should apply building and installation standards (in Czech conditions based on the Act No. 406/2000 Coll., on energy management) whether it applies to production installations, network losses or consumption.

The possible improvements of the current state are being initiated by the Czech technical working group on energy efficiency which consists of representatives from Ministry of Environment, Ministry of Trade and Industry, Agency for Integrated Prevention, State Energy Inspection, Association of Industry and Transport, Czech Energy Agency, ENVIROS company, several consultants and representatives of Energy industry.

The aim of this group’s current effort is to get involved in preparation of the IPPC act amendment, which enables to make direct link on practical application of improvements measures prepared within energy audits, especially energy management. We are proposing that the permit requires more than just description of energy efficient measures specified by the energy audit, but that it requires also information on energy management techniques and implementation in the company. Further more the energy efficiency improvement plan could be developed.

Plenary final discussion

ENERGY EFFICIENCY - A CHALLENGE FOR SUSTAINABLE DEVELOPMENT: CHANCES AND RISKS FOR IMPLEMENTATION

Herbert Aichinger, *European Commission*
Patrick Arbeau*, Solvay*
Wolfgang Brenner*, WKÖ/BSI*
Lesley James*, Friends of the earth (NGO)*
Jerry Roukens*, Consultant*
Sebastian Spaun*, VÖZ*
Otto Starzer*, EVA*
Hubert van den Bergh*, Verification Bureau*
Hans Zeinhofer*, Eurelectric*

umweltbundesamt

FINAL DISCUSSION

ENERGY EFFICIENCY – A CHALLANGE FOR SUSTAINABLE DEVELPOMENT: CHANCES AND RISKS FOR IMPLEMENTATION

Members of penal discussion

Chair: Don Litten (EIPPC Bureau)

- Herbert Aichinger (European Commission)
- Lesley James (Friends of the Earth and European Environmental Bureau)
- Sebastian Spaun (VÖZ)
- Patrick Arbeau (Solvay)
- Hubert van den Bergh (Verification Bureau)
- Otto Starzer (E.V.A.)
- Jerry Roukens (Consultant)
- Wolfgang Brenner (WKÖ/BSI)

Prior to the conference, the organisers communicated three questions to the members of the discussion. These questions were central to the discussion.

Summary of main points

Question 1: *How helpful are currently existing energy indices, energy management systems etc. for reducing industrial energy use and related environmental impact?*

Some panel members brought the benefits of energy management systems (e.g. for efficiency maintenance, for orienting decisions, for assessing and reducing negative environmental impacts) and energy indices (e.g. monitoring, comparison of performance) forward. Information on energy efficiency has been considered as very important for appropriate policy and decision making, both for regulators and for companies.

However, all members of the podium agreed that measuring and comparing energy efficiency is possible but rather complicated, mainly due to different system and quality parameters.

Question 2: *Can we expect a significant increase in industrial energy efficiency (e.g. similar to oil crisis) due to the present political and legal framework (liberalisation, IPPC, Emission trading, CHP, energy taxes etc.)?*

There was consensus on the podium that energy efficiency has been improved since decades. The main reasons for increasing energy efficiency in industry were (rising) energy costs and the application of new technologies, particularly when renewing, up-scaling or up-grading industrial installations.

It was argued that, contrary to rising energy costs as driver for energy efficiency improvements, energy liberalization and the associated reduced prices could discourage significant capital investment and end user efficiency.

In the discussion, it has been mentioned that further major improvements would require technology breakthroughs which could also be stimulated by environmental regulation. For a rise in energy efficiency, representatives of industry would welcome enforced energy management systems, information about possibilities to reduce energy use as well as Best Practice models.

Some of the main challenges with current instruments have been discussed as well. It was brought forward that some may conflict with the economy (e.g. energy taxes, IPPC), some are politically sensitive (e.g. emission trading) and some are limited by technical and economic feasibility (e.g. combined heat and power).

The expectations in the instruments Emission trading and the IPPC directive were rather controversial, their compatibility was questioned by NGO´s representative. There was a common view that whether these instruments will lead to an improvement of energy efficiency depends on how strict and in what way they are implemented.

In a wider perspective on energy efficiency, some members of the panel stated that the sectors transport, household and commerce have to be targeted as well. For combating climate change, the importance of decarbonising the fuel mix has been mentioned.

In the discussion, some panel members pointed out that a major jump in energy efficiency would require a drastic change of the current socio-economic system (e.g. life style, products, services).

Question 3: *Which additional or different instruments and incentives, respectively, marrying an increase in industrial energy efficiency and economic prosperity can be imagined?*

Penal Members representing administration and consultants considered EU-wide energy taxes as a very flexible and appropriate tool for increased efficiency. Taxation of CO_2 emissions was also mentioned as a possible tool. Setting voluntary or legal energy efficiency standards for existing products and processes was proposed.

Industry representatives argued against new requirements and claimed that information and incentives for companies would be the most appropriate way towards energy efficiency.

In the final discussion examples for financial measures such as a subsidy reform, environmental/financial incentives, investment subsidies or tax relieves were brought forward. It was stressed that financial instruments such as subsidies should not contradict environmental targets.

ENERGY EFFICIENCY – A CHALLENGE FOR SUSTAINABLE DEVELOPMENT: CHANCES AND RISKS FOR IMPLEMENTATION

Herbert Aichinger
European Commission DG Environment

Question 1

Every company is aware how much energy it uses, as the information comes with energy or fuel bills. However, measuring energy efficiency and environmental impacts is far more complicated. Environmental management schemes, such as EMAS, provide necessary analytical tools on how to assess negative impacts and how to reduce them. Benchmarking and energy indices help to put a company's performance into wider perspective of a sector or whole economy. From a perspective of a regulatory body, the information on energy efficiency and impacts on environment is crucial for appropriate policy making. There must be however a balance between administrative burdens put on companies in reporting and the need of accurate, robust data for policy making.

Question 2

Environmental regulation often spurs innovation and can stimulate technological breakthroughs. There are however two other factors that should be taken account of: energy prices and technological maturity of some industrial sectors. Significant rise of energy prices would have a positive impact on greater energy efficiency; on the other hand maturity of technologies in some sectors may limit scope of further improvement.

Question 3

EU-wide energy tax would be perhaps the most desirable and the most flexible tool. In 1980 revenue from energy taxes was below €40 billion, in 1990 almost €100 billion and in 2001 it reached €182 billion (a 4.62-time rise). We could observe as total revenue from energy taxes reached 2.1% of GDP in 2001, for comparison – revenue from other environmental taxes was only 0.6% of GDP. This clearly places the energy taxes as most popular among the member states. However, all the taxation issues are subjected to unanimity requirement in the Council, which now, with 25 members is even more difficult to achieve. As far as other instruments are concerned, the integration of environmental issues into public procurement should bring tangible results.

Conference « Energy Efficiency in IPPC – Installations »
Vienna 22nd October 2004

Participation to the plenary final discussion
(P Arbeau, Solvay, representative of the EU chemical industry)

Proposed answers and positions, in view of the questions raised in preparation of the Plenary Session:

* How helpful are currently existing energy indices, energy management systems etc. for reducing industrial energy use and related environmental impact?

The EU Chemical Industry is a major player and we are energy-intensive:
- Our **consumption** accounts for roughly 170Mtoe (3% of global and about **12% of EU energy demand**)
- Our energy **costs** account for 10 – 60% of production costs of most products >50% (>86Mtoe) used as **raw material**; rest as fuel and power.

At the same time we are competing globally with world regions with much lower energy prices.
Accordingly and inevitably, energy efficiency has been improved since decades for economic reasons. In the European chemical industry, enrgy saving used to be and still is an important element of operational management systems. Furthermore as the chemical industry usually needs steam and electric power simultaneously cogeneration which is very energy efficient is standard at most of our production sites.. As a result, our specific energy consumption per unit of output has decreased by 35% in the last 20 years.

It is correct that many indices already exist, such as efficiency of thermal installations, of cogenerations. In some countries there is an obligation to conduct energy audits aiming at helping the management of chemical industries to take the correct decisions.

These indices and the energy management systems play certainly a role in orienting the decisions. However the main incentive today is the high cost of energy in EC countries, compared with the US for instance, which endangers our competitiveness.

This is especially true now, as the price of coal, oil and electricity have increased <u>dramatically</u> in the EC these last 12 months. One can fear that this is due to a series of factors that will last in the next years, such as : the economical expansion of China, the taxes levied to support the renewable energy, the necessity to purchase carbon credits in countries outside the EC, if the reductions of emissions cannot be obtained by improvement of existing processes.

So we believe it is not necessary to put additional pressure on chemical industry for the improvement of the energy efficiency.

My own experience of energy audits, I must say, is quite deceiving. We have done a lot of work after the first energy crisis, together with consultants, and we only discovered facts and projects that we knew before.

* Can we expect a significant increase in industrial energy efficiency (e.g. similar to oil crisis) due to the present political and legal framework (liberalisation, IPPC, Emission trading, CHP, energy taxes etc.)?

No, neither existing legal framework nor prospective legislation can because a lot has already being done and we are now looking only at marginal further improvements with current technology, further major improvements will require technology breakthroughs. Like every improvement process, the low hanging fruits are the easiest to reach. In our highly efficient sector further efficiency gains will require exponentially higher effort and costs with implications for our global competitiveness.
However: major focus must also be on energy consumption reduction. This is two-fold:

1. Consumers must reduce and all sectors held accountable to do the same.
2. Giving incentives for technological solutions around lighter cars, better insulation, etc. : products that our industry can innovate to meet societal and political objectives

We are also concerned that too strict IPPC implementation might deteriorate potential benefits anticipated from ETS.
Indeed, the IPPC procedure may be helpful to review again the opportunities of energy reduction investments.

* Which additional or different instruments and incentives, respectively, marrying an increase in industrial energy efficiency and economic prosperity can be imagined?

There are means to increase E.Eff. using incentives or similar instruments. It has been demonstrated already for instance, in our sector, by the development of the CHP installations in member States. We feel that other sectors might benefit from progress made in our sector. We recommend for the BREF, drafting a general document giving basic advice, not too prescriptive in details. We advocate pursuing the establishment of a BREF for Energy Efficiency, in areas not yet covered by other BREF's.

Let me take an example and explain how a BREF for EE can be useful.

Let's consider the case of a chemical company who has to renew one boiler connected to one plant.

The key questions to be examined, for an optimal decision:

- Revised steam requirements (it is time to consider energy savings investments, in order to reduce the size of the new boiler) > Energy management and planning, Energy recovery technologies,
- Availability and costs of different combustibles > Energy indices
- Review of available technologies for the boiler and auxiliaries (consider cogeneration, renewable if biomass is an option,) > BAT for boilers, cogeneration

During nearly all the steps of the process, comparisons of the proposed solutions with the BAT can be very helpful.

Additional (for reference)

LVOC BREF was finalized in 2000. In chapter 6.3 (page 136) of that BREF there are some remarks on energy efficiency"

"BAT for energy efficiency is an appropriate combination or selection of the following techniques:
1. optimize energy conservation (e.g. by the thermal insulation of process equipment)
2. implement accounting systems that fully attribute the energy costs to each process unit
3. undertake frequent energy reviews
4. optimize heat integration at the inter-process and intra-process levels ((and where possible beyond the site boundary) by reconciling heat sources and sinks
5. use cooling systems only when the re-use of energy sources from the process has been fully exploited
6. adopt Combined Heat Power (CHP) systems where economically and technically viable"

ENERGY EFFICIENCY – A CHALLENGE FOR SUSTAINABLE DEVELOPMENT: CHANCES AND RISKS FOR IMPLEMENTATION#

Wolfgang Brenner
Austrian Federal Economic Chamber; Division Industry

Key questions:

1. *Is it necessary to create a horizontal BREF on generic energy efficiency?*

The Industry feels, that it would be better to insert necessary techniques in the sectoral Brefs during their revisions.

2. *How helpful are currently existing energy indices, energy management systems etc. for reducing industrial energy use and related environmental impact?*

The major argument for energy reducing measures in the industry are:

- Energy costs
- Applying new technologie during the renewing of the plant equipment

Energy management systems need not be enforced. Provide Information to the Industry about the possibilities to reduce energy use.

Best Practise Models can help.

3. *Can we expect a significant increase in industrial energy efficiency (e.g. similar to oil crisis) due to the present political and legal framework (liberalisation, IPPC, Emission trading, CHP, energy taxes etc.)?*

The ongoing increase on energy costs will force many companies to recalculate the energy costs. The big step towards a energy use stop is not reached. But the increasing costs, emission trading and taxes are doing their best.
But what about the traffic?

4. *Which additional or different instruments and incentives, respectively, marrying an increase in industrial energy efficiency and economic prosperity can be imagined?*

No company can be forced to use energy efficient. Information for the companies is the only way.

ENERGY EFFICIENCY – A CHALLENGE FOR SUSTAINABLE DEVELOPMENT: CHANCES AND RISKS FOR IMPLEMENTATION

Lesley James
Friends of the Earth and European Environmental Bureau

The environmental challenges facing us -- particularly climate change – will require very substantial improvements in energy efficiency over the coming decades. Faced with this, existing measures have shown themselves to be of limited use, although in theory this could be improved upon; for example, energy management systems often lack a driving force for delivering a high level of situation-specific energy efficiency improvements. However, in practice, there is limited potential for addressing this and other energy efficiency issues in the existing political and legal framework.

Within that framework, emissions trading might deliver cost savings, but it will not of itself deliver energy efficiency savings across the trading scheme as a whole: instead, it is a matter of political will as to whether any cost savings are reflected in the level of ambition of that scheme. And the potential for IPPC to deliver energy efficiency improvements has been undermined by the amendment to IPPC contained in the Greenhouse Gas Trading Directive, which makes energy efficiency standards optional under IPPC – we have no way of knowing if the potential of these standards is actually being met by trading. However, the IPPC framework could be used to deliver other significant gains in energy efficiency by introducing a BAT standard for the lifespan of plants, thereby hastening the attainment of the improved efficiencies of new plant standards and the technological development of further efficiency improvements. But equally, by reflecting traditional sectoral differentiation within industry, it could be impeding some cross-sectoral technological developments that could improve energy efficiencies by maximising plant utilisation.

CHP has long underachieved its potential, and could be addressed by changing the units upon which the LCP Directive is based from emissions/m^3 to emissions/GJ of useful energy. This would also help power plant efficiency generally. However, by contrast, energy liberalisation is unlikely to have much, if anything, to contribute to energy efficiency – the reduced prices resulting from increased competition could encourage some forms of energy efficiency, but would also deter those that require significant capital investment, as well as discouraging end user energy efficiency.

This could be mitigated by energy taxes, but these would need to be part of a much more fundamental system of environmental fiscal reform if we are to meet the scale of the challenge facing us whilst at the same time marrying industrial energy efficiency improvements with economic prosperity. New environmental taxes would need to be part of a shift away from other forms of taxation, and must be accompanied by other fiscal measures such as subsidy reform and environmental incentives. Such reform would be revenue-neutral and therefore not affect the competitiveness of industry as a whole, although specific compensatory mechanisms could be required for energy-intensive industries and low-income households. Economic reform on this scale would provide the sort of driving force for existing measures and frameworks that is necessary if we are to address the scale of the environmental problems facing us.

ENERGY EFFICIENCY – A CHALLENGE FOR SUSTAINABLE DEVELOPMENT: CHANCES AND RISKS FOR IMPLEMENTATION

Jerry Roukens
Consultant

Statement:

1. Priority is to be given to decarbonisation of the EU fuel-mix.

2. High-cost targets for CO2-emission reduction do not jeopardize EU prosperity.

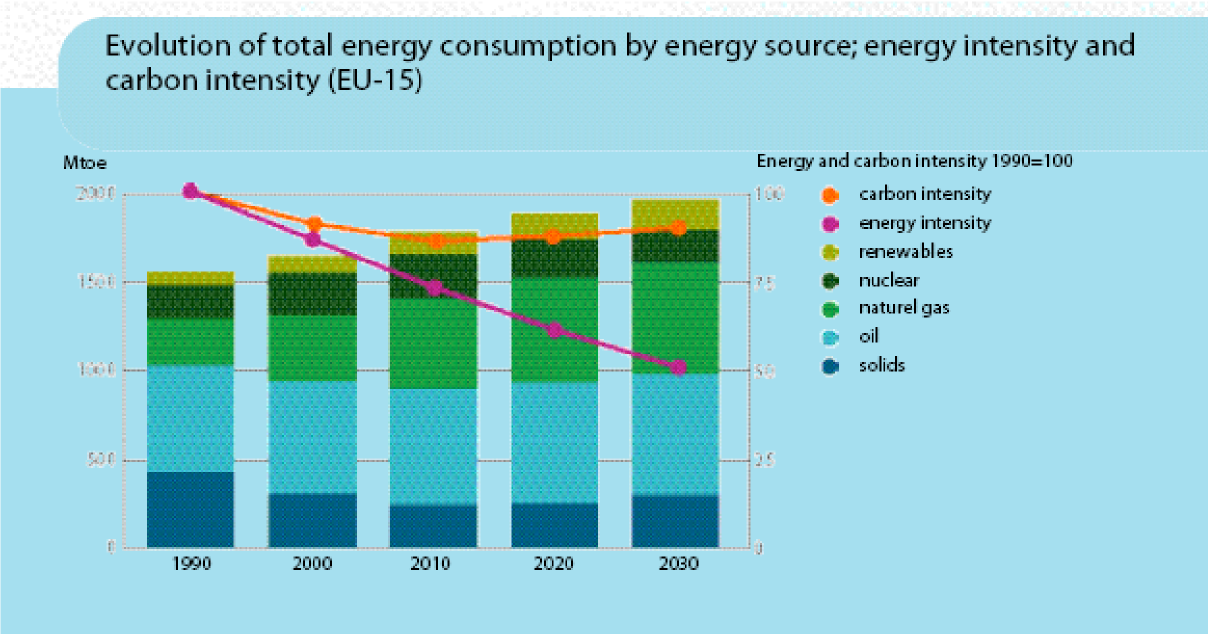
3. Tertiary sector, in particular Transport, deserves to be better targeted at for CO2 emission reduction than Industry.

4. Coordinated approach with a balanced mix of instruments is required for achieving real reductions in CO2 emissions.

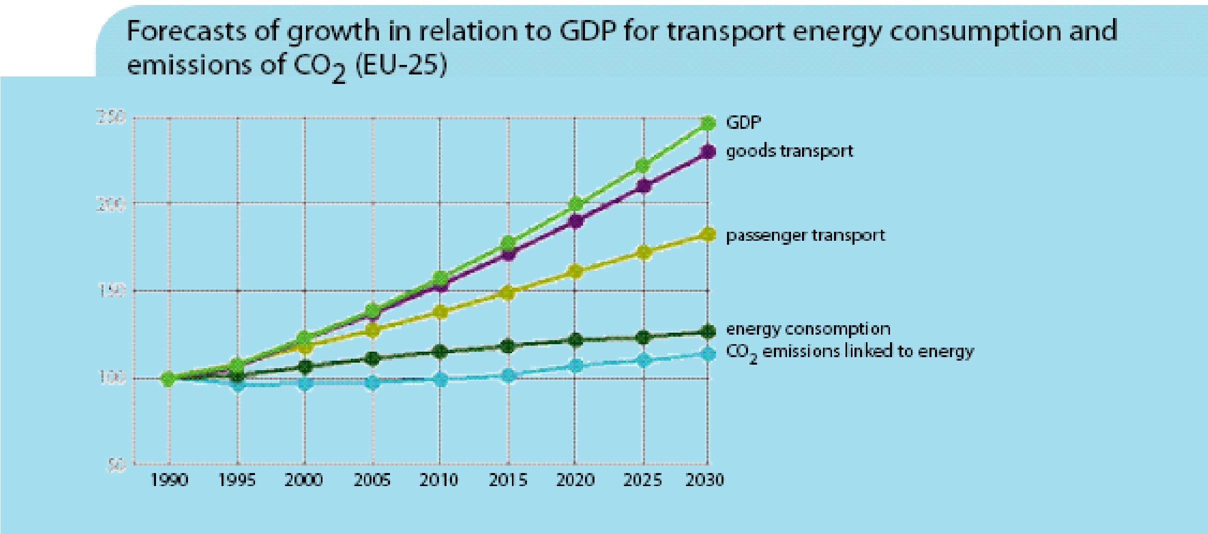
Attachment: background note

Background note, supporting statements of G. Roukens
for panel discussion at Energy-Efficiency Conference of UBA-Austria, Vienna 21-22/10/2004.

Looking at EC-scenario's (basis accepted policies and regulations)



Evolution of total energy consumption by energy source; energy intensity and carbon intensity (EU-15)



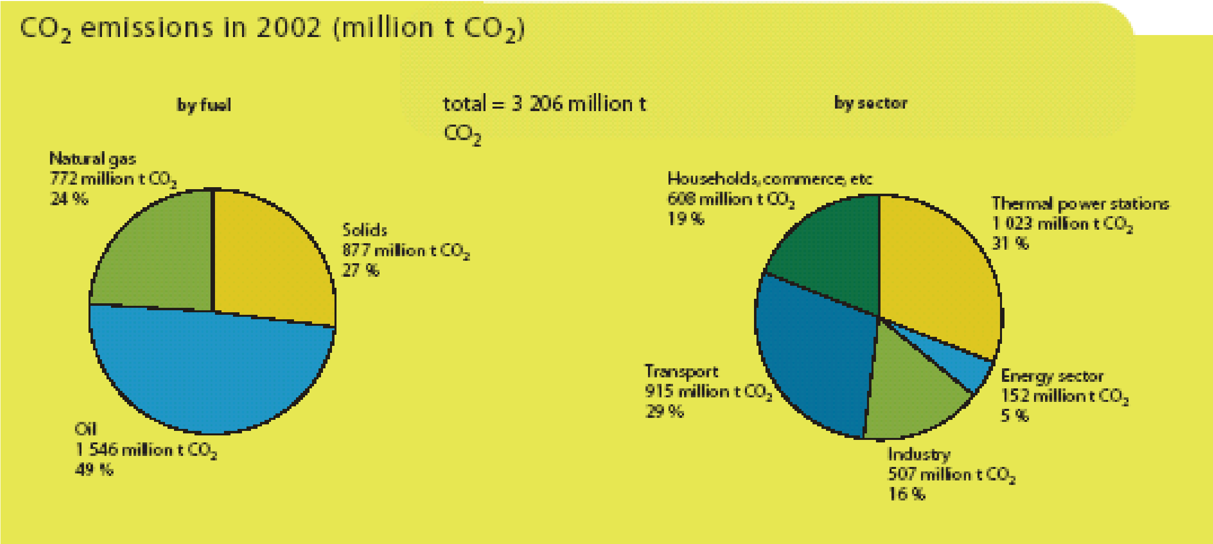
Forecasts of growth in relation to GDP for transport energy consumption and emissions of CO_2 (EU-25)

	1990	2001	2003
GDP (EU-15, bln € 1995)	**6133**	**7653**	**7784**

Conclusions:

1. The steep drop in energy intensity does not prevent energy demand to be on the rise still, CO2 emission as well. This calls for accelerated reduction of the C-intensity of the fuel mix (through fuel switch, renewables and at later stage nuclear fusion).
2. CO2 emission reduction is not jeopardising prosperity: 1000 Mton reduction at a price of 50 €/ton equals 50 bln €, i.e. less than 0,2% of the GDP in 2030 (ca. 30,000 bln €). High-cost targets are affordable.

Figures for EU-15



Final energy consumption (EU-15)

	1990	2002	2003
Energy consumtion (Mtoe)	922	1 028	*1 053*
Energy sector	63	70	*73*
Industry	265	269	*269*
Transport	253	313	*324*
Households	219	237	*249*
Commerce	79	106	*107*
Other sectors	42	32	*32*

electricity in final demand (%) 19 22 22 (one half supplied by fossil fuel plants)
primary energy supply (Mtoe) 1319 1475 1504
of which in 2002: 78% fossil fuel *), 16% nuclear and 6% renewables.
***) oil 40%, natural gas 24%, solids 15%**

Conclusions:

1. Industry & energy sector are rather stable in energy demand (ca. 32% in 2003).
2. Electricity supply, net and gross energy consumption show similar growth patterns.
3. Transport, households and commerce: largest share in energy demand, ca. 60-65%, and rising. Should be prime target now.

Coordinated approach to reduce CO2 emissions to be focused on:

- Demand side management (special attention for tertiary sectors)
- Reducing carbon-intensity of the fuel mix (a necessity; gas is on the rise already, but modest target - 12% by 2010 - for renewables is hard to reach in spite of directive),
- Supply side management (cofiring, Cogen directive, repowering),
- Promoting and developing new technologies.
  (fuel cells, solar panels, other conversion techniques, wind turbine parks at sea, the 'laddermill' harnessing wind energy up to the stratosphere, nuclear fusion, new manufacturing processes etc.).

Regulations, periodic license update (on the basis of updated env.impact assessment and Bref), permit data management (clearing house), price mechanisms, R&D support, educating and informing public, promoting the use of small cars, cheap loans and subsidies are all to be exercised in a concerted manner, with results to be monitored objectively with a maximum of transparency to the public. Agreements without real commitment to emission reductions or efficiency improvement are to be rejected. CO2 emissions-trading harbors the risk of trading 'hot air'; this does not generate reductions immediately, but buys time (yet, nature can't wait) . Project-bound JI and CDM do not have this drawback.

GR, 13/10/2004

Acknowledgement:
Graphs and associated data were taken from Report 2000-2004 on Energy & Transport, published by European Commission, DG-TREN; text of 5 July 2004, ISBN 92-894-7457-2.

Answers to the questions for the panel discussion

Q: *How helpful are currently existing energy indices, energy management systems etc. for reducing industrial energy use and related environmental impact?*

A: EMS is meant for efficiency maintenance, not for breakthroughs in plant performance. Energy indices are useful for monitoring progress of an individual plant or a homogeneous group of plants; they should be used with the utmost care when making (judgmental) comparisons.

Q: *Can we expect a significant increase in industrial energy efficiency (e.g. similar to oil crisis) due to the present political and legal framework (liberalization, IPPC, Emission trading, CHP, energy taxes etc.)?*

A: Yes, according to EC-scenario's. However, efficiency only will not save CO2 targets; decarbonisation of the fuel-mix is imperative in the long run.

Q: *Which additional or different instruments and incentives, respectively, marrying an increase in industrial energy efficiency and economic prosperity can be imagined?*

A: According to EC-scenario's, the marriage already exists. Nonetheless, bolstering and ensuring rapid efficiency improvement and fuel decarbonisation is needed. Taxation of CO2 emission, additional to CO2 trading, comes to mind. Buy credits or invest and pay tax on the remaining CO2 emission. Tax is to be used for R&D and project support. In effect, investments will be provoked, a live market for credits created, application and development of renewables stimulated, other pollutant emissions reduced, jobs and GDP pushed up, prosperity all around.

G. Roukens, 13/10/04

ENERGY EFFICIENCY – A CHALLENGE FOR SUSTAINABLE DEVELOPMENT: CHANCES AND RISKS FOR IMPLEMENTATION

Sebastian Spaun
Association of the Austrian cement industry

Answers to the key questions

Question: *How helpful are currently existing energy indices, energy management systems etc. for reducing industrial energy use and related environmental impact?*

Answer: A problem of the present BAT document “cement and lime” is that one singular BAT figure for energy efficiency does not explain the conditions under which it would apply. But since the cement production is a raw material transformation process the local conditions are a prerequisite. The energy efficiency of a cement plant is depending on the clinker capacity, the raw materials situation, the raw material moisture, as a consequence the number of cyclone stages, the lime saturation and silica ratio of the raw meal, the question if external energy is needed for the drying of the raw material, if a calciner is used, if and what size of a by pass is used, the kiln design, the kind of clinker cooler etc..

Question: *Can we expect a significant increase in industrial energy efficiency (e.g. similar to oil crisis) due to the present political and legal framework (liberalisation, IPPC, Emission trading, CHP, energy taxes etc.)?*

Answer: No. The continued effort over past years to improve energy efficiency means that there is little room for further improvement. The cement industry is a very energy intensive industry with energy typically accounting for 30 – 40 % of the production costs. So logically the optimization of the energy consumption was and is one of the crucial topics of the industry.

Question: *Which additional or different instruments and incentives, respectively, marrying an increase in industrial energy efficiency and economic prosperity can be imagined?*

Answer: We have to be careful with new requirements relating energy efficiency. The emission trading system for example is from fundamental difference compared to the IPPC approach on energy efficiency. The fact that CO_2- efficiency and energy efficiency does not go hand in hand was luckily recognized by the EC.

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Plenary Final Discussion: Input

Energy Efficiency – A challenge for Sustainable Development

Otto Starzer, E.V.A.

Question 1:
How helpful are currently existing energy indices, EM systems …?

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- **Benchmarking/ BAT:**
  - very helpful from the viewpoint of an authority, but very difficult to get comparable data and to apply
  - BAT data need updating
- **Energy Audits:**
  - old tool but good tool, applying by specialists
  - Ensure comparability and quality standards
- **Energy Management:**
  - is standard in bigger companies
  - should be stronger applied for SME
- **EMAS:**
  - good driver, but too complicated esp. for SME

Question 2:
Can we expect significant increase in industrial EE, due to present framework ?

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- **Yes & No:**
  - Yes, because EE in industry is continuously increasing, "C efficiency" by 1 % per year is economically feasible, many EE options are available
  - day-to-day optimisation esp. with production increases is taking place, but difficult to quantify
  - No, because absolute energy consumption will increase due to production increases
- **significant increases … :**
  - with change of process technology (up-scaling, process integration etc.)
  - still huge potential for industrial CHP (e.g. Repowering)

Question 3:
Which instruments / incentives increase industrial EE and econom. prosperity ?

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- **Investment subsidies for EE:**
  - Investing in EE has to be made more attractive
  - find new financing schemes, take away the risk
  - involving banks on a bigger scale
- **legal requirements:**
  - make energy management compulsory, esp. for SME
  - continuous energy analysis leads to higher EE
- **Let industry do the job but do control**
  - energy audits have to be carried out on a regular basis by real specialists
  - clear quality standards for audits
  - transparent controlling by authorities

Energy Efficiency

a Challenge for Sustainable Development

Hubert Van den Bergh

How helpful are currently existing energy indexes?

- there are few, and of little help
- energy (and CO_2) efficiency is very different from other IPPC issues:
  - they are no pollutants
  - no end of pipe technologies
  - the process is determining, retrofit often impossible
  - random conditions are important

Can we expect a significant increase in Energy Efficiency ?

- stimulation of energy efficiency has been practised since the 1970s
- further political push often conflicts with economy: liberalisation, IPPC, energy taxes
- "Emission Trading", when burdens are tight, in a rationing system, politically sensitive
- CHP: traditional technology with new techniques, limited by technical and economic feasibility

Which additional instruments marrying E.E. and economic prosperity?

- there are three levels:
  - E.E. of existing products/processes
  - E.E. product choice
  - push on economy
- for level 1:
  - stimulation, information
  - financial incentives
  - voluntary or legal standards in efficiency

Verificatiebureau Benchmarking Vlaanderen
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Plenary Discussion
Energy Efficiency – a challenge for sustainable Development

ENERGY EFFICIENCY IN THE ELECTRICITY SECTOR

Hans Zeinhofer
Energie Allianz Austria,
Energie AG Vertrieb GmbH & Co KG
Vienna, 22nd of October

General Remarks

Eurelectric – based in Brussells – represents the interests of the electricity industry of the European member states and coordinates the single and sometimes different points of view of its members and dicusses all relevant matters with policy makers in the EU.

Energy efficiency belongs to the core business of electricity generators and suppliers. The industriy therefore supports a policy to optimise energy efficiency. High energy efficiencies contribute to cost efficient operation, to conservation of fuels and to minimizing both dependence of fuel imports from outside Europe and all kinds of emissions.

A special point of attention for Eurelectric is focussed on the tuning with all relevant directives and guidelines, especially on:

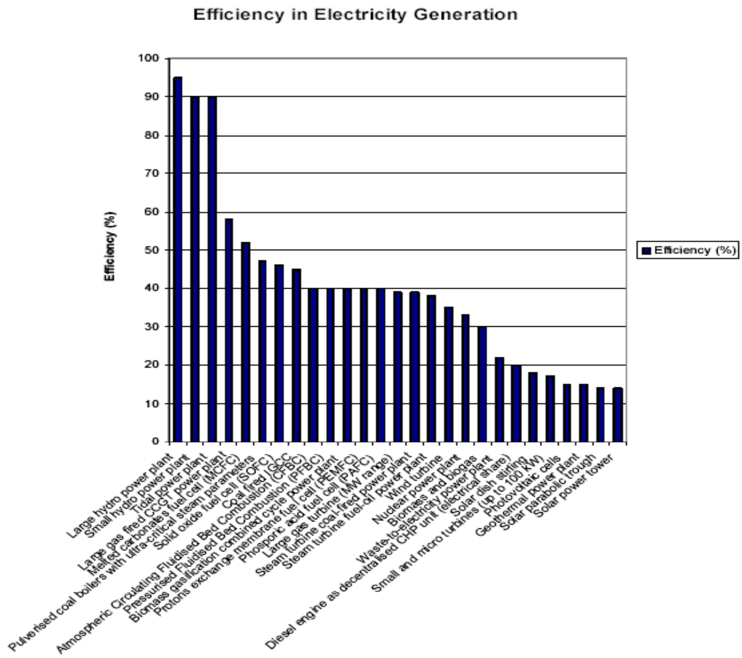
- Large Combustion Plants Directive a BREF LCP
- Energy End-Use Efficiency and Energy Services
- Promotion of Cogeneration
- Energy performance of buildings
- Renewable Energy Sources
- Emission Trading of Greenhouse Gases

Fig. 1
Energy efficiency of power generation

As figure 1 demonstrates, the efficiency is strongly depending on the type of generation and the fuel.

However, not all the types like hydro, nuclear and solar plants are IPPC installations. For this reason the following paragraphs only deal with thermal power plants above 50 MW. [1)]

[1)] Nuclear plants excluded



Development in the Efficiency of Thermal Plants

Typical average values of electric efficiencies of combined cycles(VGB, 2001)

	1985	2000	2010 (estimation)
Combined Cycle	48	58	60

Typical average values of electric efficiencies of new coal plants

	1985	2000	2010 (estimation)
Single Steam cycle	38	47	50
Integrated Gasification Combined Cycle (*emerging technology*)	40	49	55

Retrofiting existing plants may provide also interesting efficiency improvements, but are mostly rather expensive. Typical values of 36-40% are attainable.

Conclusions on trends in energy efficiency concerning generation

We conclude that high energy efficiency has always been a primary goal of the electricity industry during many decades. As the economy in a free market also requires optimum (energy) efficiency, this attitude will not change.
The CO_2-emission trading to be introduced within the EU in 2005 will effectively mean higher fuel costs and so provide an extra incentive to improve energy efficiency. The need for extra rules to improve energy efficiency in power installations is therefore very limited. The main effect of such rule will be the public demonstration that energy efficiency has already been optimised indeed as much as economically feasible.

Energy Efficiency on the Demand side

- significant improvements in the efficiency of domestic applications
- high potential in lighting
- relative small dpecific improvements by electric motors and drives (ca. 50 % of the total electricity consumption
- significant potential of electric technologies used in transport
- great potenital for (primany) energy savings from heat pumps
- energy savings (and product quality) improvement achieved by industrial applications

Industrial applications: examples for energy efficiency

- Electroheat technologies comprise high-power heating processes which are powered through electrical energy. Electroheat technologies cover a large percentage of industrial electricity consumption, ranging from 20 to 40 % within the EU.
- Due to the possibility of precise control of electroheat installations there is less material wasted and the electroheat process results in better product quality.
- In general, electroheat technologies lead to energy savings, reduced costs, reduced CO2 emissions, product quality improvements and production of new materials, e.g. thixo-forming of aluminium.
- In many cases, electric-heating applications are more energy-efficient than their alternatives, especially at high temperatures, where gas furnaces are less efficient. Optimal efficiency of an electric furnace can reach up to 95 % process efficiency, whilst the equivalent for a gas furnace is only 40 to 80 %.
- In the long term, electroheat processes will play an important role in supporting the development of new technologies such as nanoelectronics and optoelectronics.

Other industrial applications using electricity for a better efficiency

- Electrodeposition (e.g. for recycling of metals present in liquide waste)
- Electrolysis (e.g. for the synthesis of nylon)
- Membrane technologies: micro-, ultra-, nanofiltration, reverse osmosis
- Industrial refrigeration, heat recuperation, heat pumps
- Mechanical vapour compression

In many cases the use of modern electrotechnologies can reduce the energy consumption by 90 percent compared to conventional technologies.