ANNEX IV: TECHNICAL POSSIBILITIES TO ACHIEVE MORE ENERGY EFFICIENCY

IV.1 BACKGROUND

This summary will give some answers and suggestions about what is possible and ways to aim at this target. In no way though are these the only possibilities. As an introduction there is a brief overview of the present energy use in the EU, based on information from Energy and Environment in the European Union (2002).

Users of energy can be divided into three groups: manufacturing and power supply, household and services (having a similar structure of energy use) and traffic. It can be said that all “users” have nearly the same ratio of total energy consumption. Here only the manufacturing and power supply sector is described as those installations need an environmental permit. The present situation in the manufacturing and power supply sector and the related problems are presented here.

IV.1.1 Manufacturing and power supply

A switch in demand to more electricity offsets the present improvements in energy efficiency in power supply units (5 % in electricity production). The positive effect has been cancelled because the conversion rate of producing electricity is lower than that of producing heat. However, there is still considerable potential to save energy in this sector.

The manufacturing sector has also already improved its energy efficiency through structural changes, import substitutions, changes to less energy intensive processes, and direct improvements in energy efficiency. Up to now it was not possible to decouple economic growth from energy demand; however, to improve energy efficiency, the improvements must be made at the same rate as the economic progress. This is possible, particularly in this sector, because there is a lot of potential to save energy, especially by implementing the requirements of the IPPC directive in the permit procedure. This means using other technologies (e.g. according to the BREFs) and other approaches.

It is unlikely that with the current situation of rising living standards and falling energy prices there will be a reduction in energy demand. Instead, energy efficiency should be improved in order to reduce the present energy consumption without lowering living standards. Improving energy efficiency would also lead to decoupling economic growth from energy demand and less pollution.

IV.1.2 Measuring energy efficiency

It is difficult to find one definition of energy efficiency. The starting point for defining energy efficiency in this summary is taken from the Integrated Pollution Prevention and Control… (2002). It says that "…emissions of carbon dioxide are generally used as the primary indicator when assessing the environmental impact of energy use". Assuming that all efforts that will be done in improving energy efficiency should lead to a reduction of carbon dioxide emissions, it can be said that improving energy efficiency means the following:

Improvement of the ratio of input energy to bound energy, that is energy contained in the product, should be done in a way that the carbon dioxide emissions stay at least at the same level. In other words, to minimise losses of energy, the processes have to approximate as close as possible the technical optimum, in consideration of emissions.

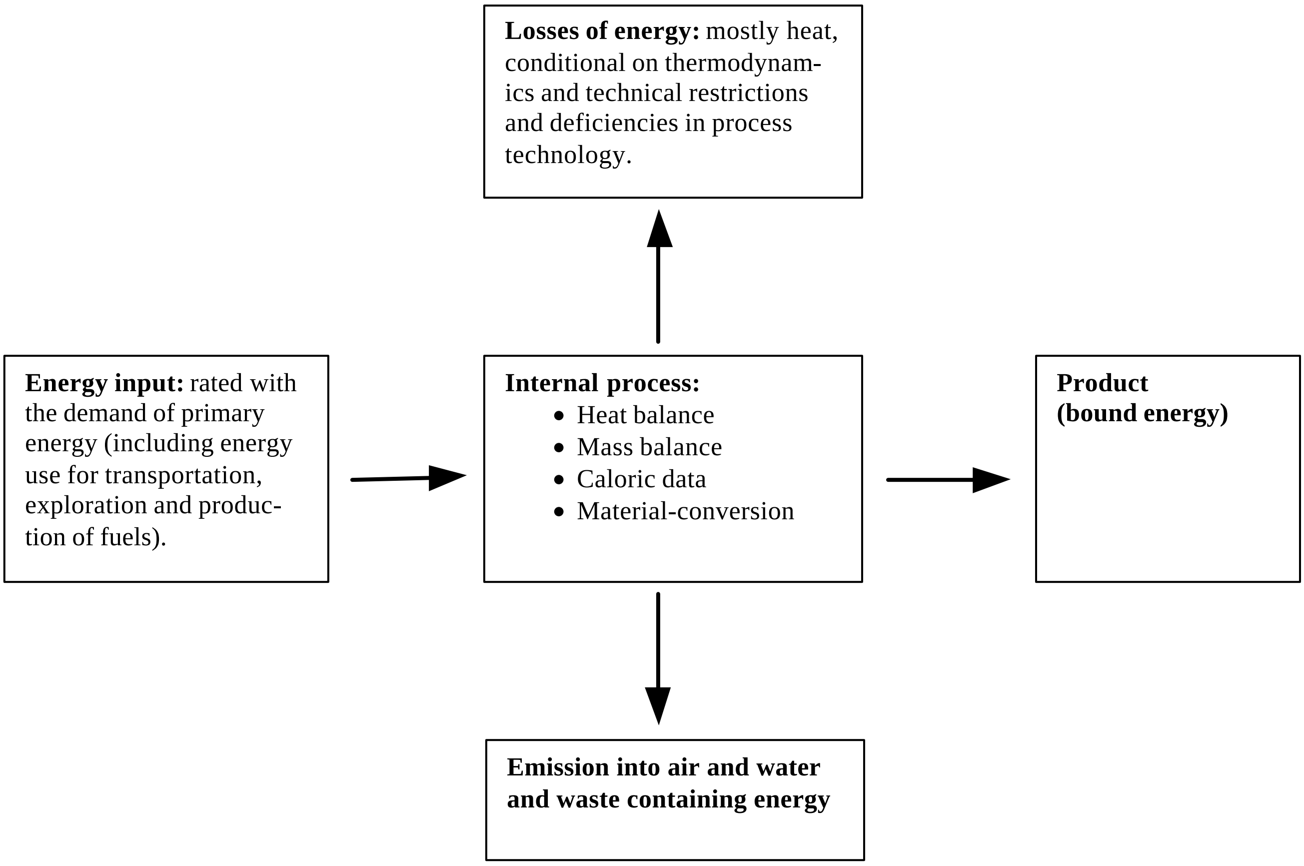


FIGURE IV.1. Energy flows in an installation (Thomas Kohl).

Quantification

It is possible to get a first rough estimation of the energy efficiency of a plant by monitoring the ratio between input energy and bound energy, because emissions and losses are relatively easy to measure with existing techniques. The energy contained in the products is the difference between input energy and the process losses and the energy content of emissions and waste as shown in Figure IV.1.

This balance checking means that company data on fuel and energy consumption, energy production and losses are needed. Confidential data about the internal process (a "black box") are not needed for this first estimation. To gain comparable data requires a valuation of the input; a good data source for the input would be the primary energy demand of the installation, that is, if electricity is used, the conversion rate and transfer losses have to be taken into consideration. A common unit to express the amount of energy use is also needed, for example toe, GJ or kWh. Once these data are collected, it is possible to do a benchmark comparing the ratios of different companies. This would provide an overview of the energy efficiency of companies in the EU. An analysis of the data would lead to a value of best energy efficiency, which would be a target value for other companies to aim at. Except for the data on losses, the tools or the systems to gather these data are already available in most EU countries, based on the answers given in the questionnaire (Annex I, Table 84).

After a rough monitoring of energy efficiency (see Figure IV.1), the next requirement is to find a tool to improve energy efficiency. The next part of this summary will show that much can be done to improve processes. To measure these "internal" improvements, process data (as shown in Figure IV.1) will be needed; but this data are mostly confidential because they expose the company or production secrets.

The companies are able to introduce a self-monitoring programme and to calculate the specific energy consumption (SEC), expressed, for example by kWh per produced unit, and to convey this result to the authorities. To do this, the company has to check all process streams, which helps to determine where in the process the most gains in energy efficiency can be achieved.

Once the company knows which points in the process can be improved, it calculates whether the improvement is cost-effective or not. If it is, the company will change the process to be more energy efficient. This information together with information on the technology used would give guidance on what is possible and what is the best available technique. The challenge in using this method is to collect the data and analyse it in a way that it is comparable. However, by gathering these data and having the skill to analyse these masses of data one can say how close a company is to the optimum or in which companies special measures are necessary to lead them to more energy efficient operations. As mentioned above, the optimum would be gaining a self-regulating system for tracking improved energy efficiency to lower costs.

IV.1.3 Potential to improve energy efficiency in the IPPC sectors

According to the AEA report (Haworth et al. 2000), the potential energy savings in Table IV.1 are within reach. Qualifications of the numbers are explained in Section IV.2.

TABLE IV.1. Potential energy savings by IPPC sector.
Tables 5.3 and 5.4 from the report by Haworth et al. (2000) are amalgamated.

Sector	**IPPC coverage (%)**	**Saving potential (PJ)**	**Saving potential (%)**	**Confidence level**
Steel	100	387	15	+++
Refineries	100	770–980	25–32	++
Large combustion plants	98	1 830	6	++
Paper	98	380–440	21–24	++
Non-ferrous metals	97	147	21	+++
Non-metallic minerals	86	152	13	+
Chemicals	74	460–790 (240–350)	16–27 (8–12)	++
Textiles	34	70–80	12–14	+
Food	31	140–180 (100–120)	9–12 (6–8)	++
Livestock	2	~2	10	+
Waste management	Not calculated	40–90	n. a.	+
Tanneries	Not quantified	not quantified		--
Manufacture of coke	Not quantified	not quantified		--
Production of carbon	Not quantified	not quantified		--
Gasification	Only demonstration plants	n. a.	n. a.	--

+++	Energy consumption data and opportunities data well defined in this sector.
++	Most countries have good data by detailed sub-sector. However, some information needed to be estimated from more limited data.
+	Little data available at detailed level.
--	No reliable data available to make an estimate for the EU 15.
n.a.	Not available.

The values written in brackets assume that CHP replaces gas turbines instead of the average energy mix.

Methodology and confidence level

The values in Table IV.1 were calculated from, when possible, a benchmark between the actual SEC and a reference SEC achievable in changing to more energy efficient operations by using other technologies or other non-technical approaches, for example energy management. For a consistent benchmark, detailed data on the sector concerned and the corresponding sub-sectors are needed; however, this was possible only for the steel sector.

For all the other sectors, different methods were used, which resulted in different confidence levels. The problem was that for these IPPC sectors detailed energy data were insufficient to determine an exact SEC, because the lower the energy costs in the production of a product, the less detailed energy data are available. In the EU, economic, production and energy data are handled through the NACE system.

The NACE system gives every sector a code (e.g. 17 for textiles) and classifies the sector further into sub-sectors with a second number (e.g. 17.2 for weaving mills), and for more detailed information adds one digit more (e.g. 17.21 for cotton weaving mills). This is called the NACE four-digit-level. To generate exact benchmark values one needs the most disaggregated data that is on the four-digit-level. A wide range of data is also needed, in other words, the majority of the industries have to be considered. This is expressed by the IPPC coverage cipher that explains which part of the sector is registered by the EU authorities. However, energy data at the NACE 4-level exists, as mentioned above, for only one sector: steel production, in which energy is one of the highest expenditures.

Only large companies are covered by IPPC, because the scope of the directive is limited to installations with a certain minimal output. Thus, industrial sectors with smaller production units and decentralised facilities are not covered. The problem of inadequate data sources is sector and country specific. This means that for all the other sectors estimates were needed to gain comparable figures. Energy estimates at the sub-sector level were based on activity data as sub-sector value added (monetary value) or physical production (such as tonnages). Additionally, numbers from geographically and economically comparable countries were used to give useful values. Therefore, the lower the disaggregation, and the worse the data availability in the Member States is, the more estimation is needed, resulting in a lower confidence level.

IV.2 DESCRIPTION OF METHODS USED TO ACHIEVE ENERGY EFFICIENCY

In the AEA report the measures for achieving energy savings and improving energy efficiency were classified into four categories:

- savings by improving process technology
- savings by adding more combined heat and power (CHP)
- savings by better energy management
- cross-sectoral devices

The values in Table IV.2 below are not exact figures but rather targets, as are the figures in Table IV.1. There are uncertainties resulting from inadequate data; hence, some of the values are underestimated while others are overestimated. The uncertainties and the confidence level of the figures will be explained for the measures in Table IV.2.

TABLE IV.2. Contribution of different technological measures to potential energy savings.
Table modified from the report by Haworth et al. (2000).

Type of measures	**Energy Contribution (PJ)**	**% of total savings**
Process technology	1 952	51
Combined heat and power (CHP)	1 325*	36
Energy Management	311	8
Cross-sector device	208	5

*Note: The assumption here is that CHP will replace the average mix of energy-generating technologies. However, according to other studies it is possible that CHP will be substituted for other highly efficient technologies, like CCGT, because of being a marginal technology. This would lead to fewer savings so that the quoted value is understood to be a maximum.

IV.2.1 Process technology

Most improvements in energy efficiency are achieved by upgrading processes. This report describes many sector-specific and precisely defined techniques, but the technical details are beyond the scope of this summary. Additionally the measures mentioned in this report are not adjusted to the BREFs (they are identified in a previous Thermie study (Fletcher et al. 1999)).

Some of the studied technologies are only cost-effective when integrated into new plants or production lines as the physical and economic life of production lines and plants are rather long. This means that the targets in Table IV.2 are not reachable in the short term.

To improve energy efficiency by improving processes will generally lead to lower costs because of reduced fuel and energy use and because of higher product quality and quicker throughput. In contrast, end-of-pipe technologies cost money and it is possible that they will increase the energy demand (thus decreasing the energy efficiency) in reducing emissions. For these reasons, improving energy efficiency has a synergy effect – it improves processes and saves energy, while it reducing emissions and costs.

The techniques investigated in the Thermie study are used in the AEA report (Haworth et al. 2000) since they can be regarded as having long-term cost-effective potential to reduce emissions by improving energy efficiency; unless there are technical restrictions or barriers to their introduction such as restrictions on capital. To consider the costs of the technological opportunities the measures were valued at a 25 % discount rate and a five-year depreciation period (corresponding to a payback in two years).

Now, having a rough estimation which savings, respectively, improvements are possible, the aim is to find a tool to measure, monitor and improve energy efficiency. One possibility is the pinch technology. This tool should be abstract and applicable in all sectors for using it in permission process to gain comparable data with as little modification as possible. The basic approach for all sectors would be the same: the heat and mass balance is checked and an evaluation of the internal processes is carried out; with this information, opportunities to improve energy efficiency will be researched as explained in the following. As mentioned in the first part of this summary this approach could lead to a type of self-regulating system. Section IV.2.2 describes what the idea of pinch technology is, how it is used and what for results are expectable.

IV.2.2 Pinch technology

Introduction

Pinch technology, or pinch analysis, was developed by Linnhoff March (UK) in the end of the 1970s to optimise thermodynamic processes. Experiences have shown that notable energy savings are reachable. The savings are between 10 % and 40 % mostly related to low or moderate costs.

This technology is very variable and is applicable both in new projects and retrofit projects and is used in nearly all branches with success, even in non-industrial branches, such as hospitals. In this report pinch technology is explained for a single process, but it is also applicable to an entire site, as a site is made up of many single processes.

Pinch technology is based on heat recovery in thermal processes; the resulting energy saving leads to a reduction of air pollutants (SO_2, CO_2 and NO_x). It is important to know that heat is the poorest form of energy and that it normally makes no sense to transform process heat into a higher grade form of energy, but that it is always possible to transfer heat from one mass flow to another if the temperature difference are sufficient.

Modus operandi of pinch technology

Pinch analysis is divided into several sections that will be explained in a brief and non-technical manner; however, some thermodynamic elements are inevitable because they are fundamental to understanding this technology.

Mass and heat balance/thermal data

The first step is to investigate the basic reactions of the process, and based on these facts, to define the existing mass and heat flows (pressures, temperatures and heat capacities). The best way to get this information is to use existing process-simulation programs. If these are unavailable, descriptions of the equipment or operation data can be used.

Data extraction

With the thermal data, heat and cooling energy is appointed under consideration of the potential of internal heat transmission without having regard to existing heat exchangers, as long as they are not essential for the process. The exclusion of heat exchangers will be explained later. Flows are now separated into one hot flow (which means it needs cooling) and one cold flow (which means it needs heating).

The starting point of pinch analysis is the assumption that almost all cooling energy can be seen in a relationship to heating energy, that is, hot flows can heat the cold ones by cooling themselves down. The energy that is not available in the process has to be provided by the utility flow, that is from the outside. The utility flow itself can be gained from another production (process) line (total site technology).

The pinch principle and energy targets

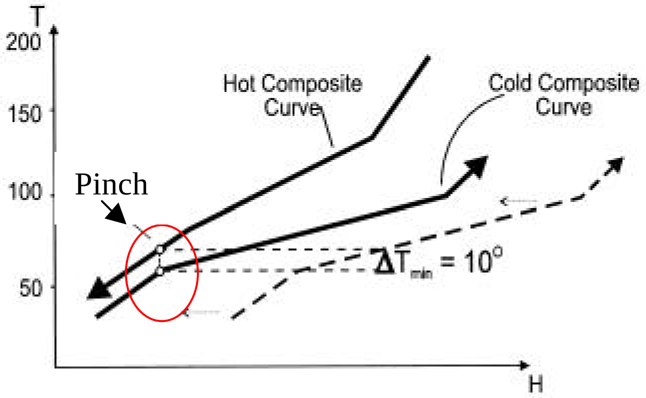


FIGURE IV.2

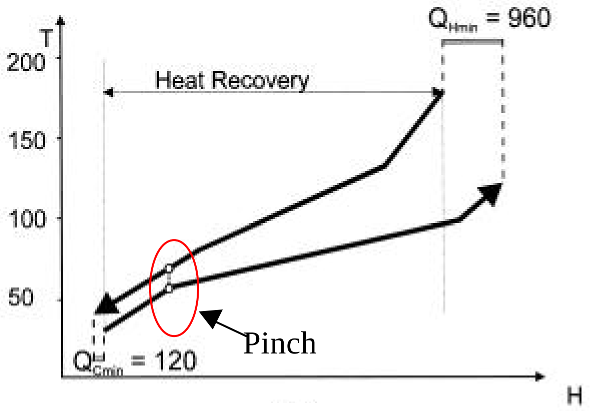


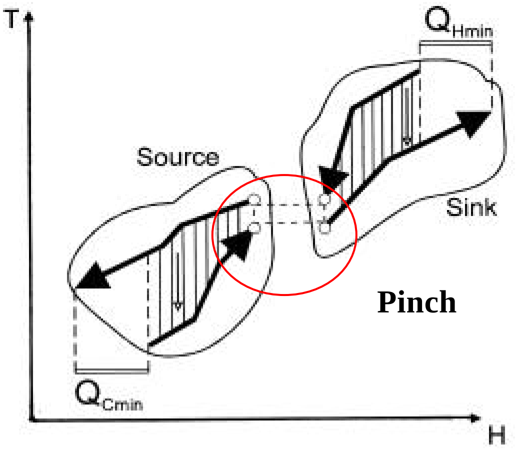
FIGURE IV.3

(Figures from Introduction to Pinch Technology 1998).

As shown in Figure IV.2, there is a minimal temperature difference (ΔT_{Min} here: 10°) under which heat transfer is no longer possible because of economic and thermodynamic reasons (the heat transfer area begins to increase). Hot and cold flows are opposed (Figure IV.2) by using the so-called composite curves and analysed for the best possible heat recovery. Doing this gives the pinch as a result.

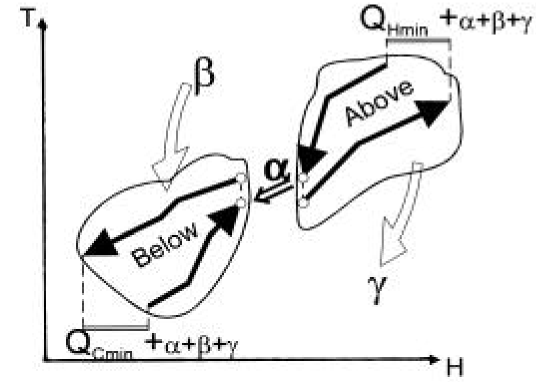
What is the pinch? The comparison of the hot and the cold flows results in a specified temperature (depending on the studied process, here about 60°) at which the temperature difference of both flows is similar to the minimal temperature needed (Figure IV.3).

After the pinch has been determined, it is possible to identify the minimum process energy needed: Q_{Cmin} for cooling and Q_{Hmin} for heating. The remaining energy can be gained by internal heat recovery.



The pinch divides the problem into source and sink

FIGURE IV.4



By violating the three golden rules Q_{Hmin} and Q_{Cmin} are each increased by α+β+γ.

FIGURE IV.5

(Figures from Introduction to Pinch Technology 1998).

What is the significance of the pinch for the process management? The process is now divided into two systems (Figure IV.4): one system above the pinch that only needs heating (heat sink) and another below the pinch that only needs cooling (heat source).

As the two systems together with the associated utility flows (one for cooling, one for heating) are in thermodynamic balance, it makes no sense to transfer heat between the them (Figure IV.5). For example, transferring heat from the heat sink to the heat source (flow α) results in a higher power demand, because the cold system needs more cooling and the warm one, more heating.

This means that every heat transfer across the pinch, every heat addition below the pinch (flow β) and any heat removal above the pinch (flow γ) result in a higher total energy demand. The energy targets represent the minimal energy input needed, calculated with pinch technology from the extracted data.

As mentioned above, ΔT_{Min} not only depends on thermodynamic aspects but also on economic ones. The lower ΔT_{Min} is set, the lower the utility flow demand, but investments are higher for the heat exchanger. Pinch technology also calculates and optimises the investments. Hence, energy saving effects (i.e. saving money) are set against the costs of the needed process changes and of new acquisitions and are thus optimised.

Optimisation of utility flow and process modification

After finishing this analysis, it is now apparent in which parts of the process:

- the input of high-class and expensive heating or cooling agents can be reduced, or substituted with cheaper ones, such as ones with lower energy levels (e.g. using water instead of a cooling agent or medium-pressure steam instead of high-pressure steam);
- notable energy savings result only from small modifications in the process conditions;
- heat pumps, thermal engines and turbines are integrated sensibly; and
- modifications in the existing heat exchangers are necessary so that they no longer transfer heat across the pinch. This is the reason why they are excluded from the analysis.

Possible integration of pinch technology into the permit procedure

Pinch technology can be seen as a useful tool leading to better energy efficiency. It could become part of a benchmark system, as in the Netherlands, resulting in more exactly defined guidelines on how to perform a benchmark. With a common strategy, benchmarking would lead to more comparable results as the modus operandi would be the same.

The actual situation is as follows. The aim of this voluntary agreement between companies willing to join and the authority is to aim at the Netherlands' Kyoto dues concerning the reduction of carbon dioxide emissions.

The Netherlands has chosen to reach its Kyoto commitments through voluntary agreements in which the participating companies are obliged to report on their current state of energy efficiency. The report is prepared by a third, neutral party (probably an energy-consulting company). The results are to be delivered to the authority, that is checking if the thermal and energy data is detailed enough to make a convenient statement about the energy efficiency of the company. If not, the authority is allowed to ask for further information. The third party defines the so-called best international standards by using domestic technical information and/or technology information from foreign countries or companies. The participating companies must achieve the best international standards by 2008–2012.

However, it is not guaranteed that really comparable data will be gained by the investigation. There are many ways to gather data, so it would be worthwhile to have a common way to do so. This could be done with pinch technology. It gives guidelines on which data are needed and how to treat the data, and it can, as mentioned above, be used for many production processes.

Pinch technology would thus be a convenient instrument, as it is somewhat abstract, to be included in a permit procedure. The results are promising as an Italian study shows. Italy is investigating the methodology's effects on implementation in the permit procedure. The study is already finished and the usefulness of pinch technology is obvious. The Italian authorities used pinch technology to investigate a chemical plant; the outcome was that reasonable improvements are possible.

The following is quoted from Pini et al.:

> "Conclusions: With regard to our purposes, this work confirmed the usefulness of the adopted methodology in order to evaluate the energy performance of industrial plants. The implemented procedure has a very easy and linear development, allowing an easy access to all its steps, in particular to the data input

> and check. The results here presented are affected by the uncertainties connected to the data origin. An increasing effectiveness of the method is expected when using actual process data.
>
> The procedure fits well the energy efficiency concept because it allows, as explained in the previous sections, to quantify the minimum energy consumption of a plant and the subsequent potential saving. Moreover, the applied procedure offers the tools to understand the way the energy savings can be obtained. Finally the analysis is carried out taking into consideration the economic issues, suggesting proper solutions in the assessment of the utilities.”.

IV.2.3 Combined heat and power (CHP)

Combined heat and power, also known as cogeneration, is a process technology that generates energy out of primary sources into both electric and thermal energy. In contrast to a power plant in condensation mode the overall efficiency can reach up to 90 %, and with high technology even more. A modern condensation mode plant can achieve only up to 40 % efficiency, except for CCGT[1] (Combined Cycle Gas Turbine), which has an efficiency of about 60 %. The difference between the CHP plant and a conventional one is that the CHP plant, if operated optimally, has no cooling system in which the process water is reconverted by emitting heat to the environment. As shown in Figure IV.6, the CHP plant distributes the waste heat to a district heating network, or if the plant is part of the power supply of a company the heat is used in the form of steam or hot water as a power source. Electricity that cannot be used by the company is fed to the grid.

Figure IV.6 is a basic scheme of an extraction power plant. The fuel is burned in a combustion chamber, which heats the water in a boiler to produce high-pressurised steam, as is done in a conventional plant (back pressure mode). The steam is transformed into mechanical energy in the turbine and the hot fluid or at least some of it (non-optimum scenario) is extracted to a heating network. The contingent excess heat is emitted to a cooling system. Power plants operating in condensing mode extract all heat not needed in the cooling system and release it to rivers (typically 8–10°C higher than the cooling water intake), which can cause environmental impacts. Other process losses, for example, flue gas losses, and mechanical, electrical and other heat losses, are similar for both kinds of technologies.

The assumption for the reasonable use of CHP is that there is a real demand for heat so that the “by-product” heat is used in a sensible way. In other words, if the heat produced by a CHP plant is not used, there is hardly any difference between a CHP plant and a plant operating in the condensing mode.

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[1] CCGT: Combined Cycle Gas Turbine technology is using both the kinetic energy of the combusted gas in a gas turbine as well as the heat energy of the exhausts in a conventional steam turbine by using steam. The efficiency is up to 55 % and expected to increase in further developments.

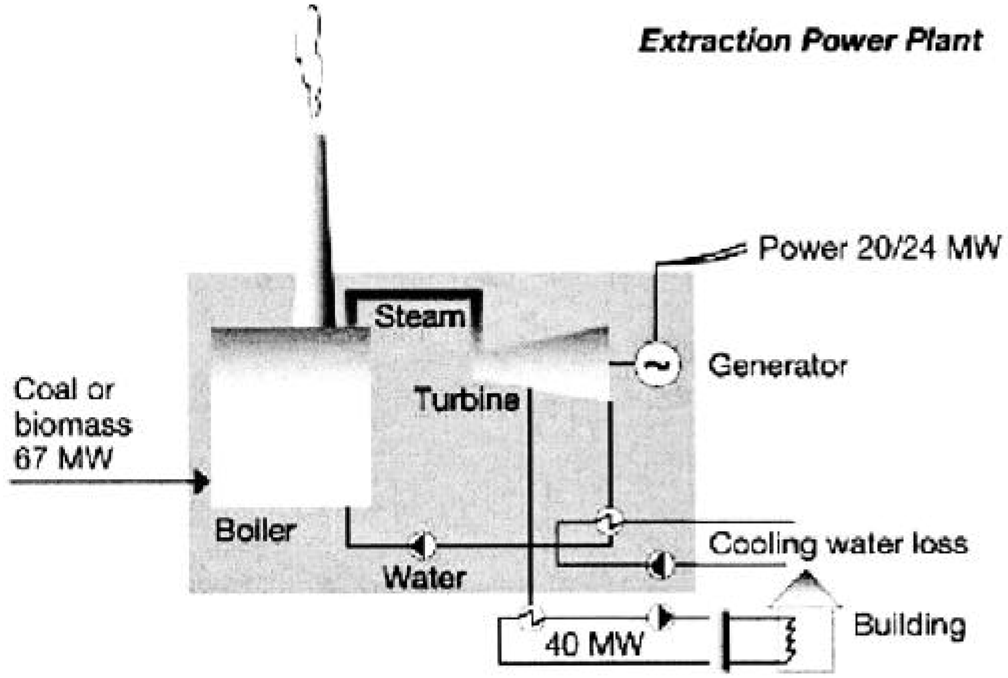

FIGURE IV.6. Extraction power plant. (Source: SAVE CHP/DHC: Evaluation of… 2000).

Qualification of the figures

The saving potentials shown in Table IV.2 are to be seen under the following limitation. The assumption of the study is that CHP replaces the average energy mix, but it is expectable that in some countries where the CCGT technique is marginal CHP will replace CCGT plants having an efficiency of more than 55 %. This would considerably decrease the impact of CHP to the total savings.

The potential energy savings are taken from the Thermie study that investigated the cost-effective saving potential of CHP. The cost-effectiveness can be very high for CHP plants, but it is unlikely that all cost-effective measures will be introduced. Finally, some of the measures are effective only when building new plants or retrofitting old ones because the estimations are based on the fact that only the newest CHP technology will be used.

The result is that the savings are to be seen as a best-case scenario. Requiring the use of CHP is no short-term measure because, on the one hand, the capital investment for CHP plants is high and, on the other, the lifecycle of existing older and less efficient plants is quite long (about 15–25 years). However, those savings are technically contingent.

Difference between electricity generated in the condensing mode and the “real CHP” mode

The Union of the Electricity Industry (EURELECTRIC) has investigated the difference between electricity produced by a CHP plant either in the condensing mode or in the “real CHP” mode. EURELECTRIC concluded that there are CHP plants with a worse total conversion rate than heat-only plants or plants operating in the condensing mode. First, “real CHP electricity” is defined.

Since CHP is only a technique used to produce heat and power simultaneously, CHP makes no prediction whether the produced heat is really used. The EURELECTRIC definition of CHP goes beyond the scope of the technical one: “real CHP electricity” is only that part of the produced electricity that is linked with a sensible use of heat. Sensible use of heat can mean use inside the production plant in the form of hot water or steam or use in a district heating network. If not used by the plant itself the assumption is that if a customer is paying for the heat, the power is used sensibly.

The problem is that many CHP plants can operate in full back pressure mode (i.e. maximum heat use) and also in full condensing mode. The mode can mostly be continuously variable. Protermo, a Finnish company, has developed a method to monitor plants by considering the ratio of the real CHP mode to the “condensing mode CHP”. As this summary does not aim to discuss the number of existing power plants that are working sensibly, no further presentation of the report’s results is provided.

Nevertheless, there is consensus that CHP plants should be regarded from this aspect, since CHP can improve energy efficiency if operated in the back pressure mode. If this is not possible, the overall efficiency of CHP is no higher than that of a conventional plant, and can even be less, if compared to a CCGT plant with potential energy efficiency of up to 60 %. Moreover, emission savings are only possible if the efficiency is improved, because the two are directly connected.

CHP and district heating

A CHP plant produces electricity and heat simultaneously with the effect that the input energy is utilised to a higher degree. The average efficiency of an electricity producer is about 32–35 % with the potential to improve it by around 40 %. However, the production efficiency of a CHP plant can be over 90 %, as the waste heat energy is used either in a process (e.g. in the form of steam) or in a heating network. Hence, using CHP plants for generating usable energy improves efficiency considerably. CHP plants use up to 90 % (modern plants even more) of the energy released by fuel combustion. Another application for CHP plants is the use in district cooling systems. Currently, this technology is experimental.

The losses in the heating pipe network increase with the distance; thus, the consumers should be located as close as possible to the plant. CHP plants can be either small-scale units or centrally located generating plants. However, large CHP power plants situated far from inhabited areas cannot take advantage of the whole potential of CHP because the heat losses and the network costs to reach the customers would be so high that using the technology would be inefficient and uneconomic.

Normally the demand for heat is lower than for electricity and therefore power plants will produce unused heat. This situation can be improved by increasing the electricity to heat ratio, for example with combined cycle technology. However, CHP can lead to better energy efficiency in the IPPC sectors by building more small-unit plants with high efficiency, especially in production plants with a high demand for heat (for example in the pulp and paper sector about 48 % of the possible savings results from CHP).

At the same time, the efficiency of CHP plants situated close to inhabited areas could be improved if the waste heat is fed into a district heating network. Doing so does not improve the efficiency of the process but rather the total energy efficiency of the plant.

IV.2.4 Energy management

Improving a company's internal energy management is a low cost measure that involves setting up a management system to monitor and reduce energy use (mainly by organisational changes). The advantage of this is that it is linked with moderate costs and is achievable in a short time. As this measure is not directly linked with technical knowledge it is not regarded intensively. Nevertheless, improving energy management can also be a considerable contribution to more efficient energy use, with the advantages mentioned above.

IV.2.5 Cross-sector devices

Cross-sector devices are energy saving technologies such as motors, drives and boilers. The potential of this measure can also be affected by pinch technology if they are applied to a total site or several companies located in the same area co-operate in their use. It is important to note that this measure is possible in the short term at moderate costs. However, the AEA report mentions cross-sector devices only as regards their contribution to energy savings.

IV.3 SUMMARY ON TECHNICAL POSSIBILITIES

IV.3.1 General

The IPPC directive obliges the EU countries to use energy efficiently. But no further guidelines are given. In fact, energy efficiency has already improved in the IPPC sectors but further improvements are necessary. The goal is to reduce carbon dioxide emissions as the EU agreed in the Kyoto protocol. Due to the fact that energy savings are hardly to be instructed and a decreasing power demand is also unlikely, the way to reduce energy consumption is to improve energy efficiency.

This report defines energy efficiency as: improving the ratio of input energy to bound energy in a way that carbon dioxide emissions stay at least at the same level. This would lead to a reasonable living standard combined with less energy use, and would also result in less emissions. In time, it may also lead to improved living standards combined with a decreased energy demand and declining carbon dioxide emissions.

The first task is to find figures to evaluate energy efficiency. This is important because without such comparable figures it is impossible to make a prediction about the state of energy efficiency. Also, propositions about the potential for further improvements are impossible. The total energy balance of a power production plant is relatively easy to measure, because all input energy is used to produce usable energy. Thus, only the ratio between input and output has to be considered. This is the easiest calculation for an energy efficiency figure. Efficiency figures should always be applied to the use of primary sources because they include the total carbon dioxide emitted to the environment.

The power production sector is the "source" of most of the used energy. This means that if the power supply industry is improving its efficiency, the total IPPC efficiency will improve because the sectors have less need for primary energy. Other sectors (household, service and traffic) would also benefit from improved efficiency for the same reason. Although the power supply sector can do much to improve energy efficiency, the contribution of other industries should not be ignored.

In order to be able to allocate figures for the other IPPC sectors, the method has to be changed. The energy content of a specific product is not as easy to measure as power is (usually in watts). This can be calculated by monitoring the input and losses.

To calculate the energy content of a product, that is, the specific energy consumption (SEC), more detailed energy data are needed. These numbers are comparable within the sector's plants. In this way it is possible to determine the potential of energy efficiency standards achievable by date and to monitor or control companies by requiring them to investigate the SEC results. However, the end-result of this monitoring system is a self-regulating monitoring system that leads to more energy efficiency. One restriction would be that the measures taken to reach this target would have to be profitable. But, most of them are as they reduce fuel costs and sometimes also lead to improved product quality. However, some of the measures, such as combined heat and power (CHP), are long-term investments because of the long lifecycle of the installations.

Because of the differences in data availability (most sectors do not have enough specific data to calculate figures with a high degree of confidence), the confidence level varies in the different sectors. The range of the savings varies by 15–30 %. The overall potential of improved energy efficiency in the IPPC sectors is primary energy savings of 12–14 %.

The emission savings are connected to energy savings in conformance with the definition given above. As a synergy effect improvements in energy efficiency will decrease emissions. The overall potential of emission savings linked with improved energy efficiency is 8–11 %.

The ways to improve energy efficiency were separated into the following categories:

- savings by improving process technology
- savings by adding more combined heat and power (CHP)
- savings by better energy management
- cross-sector device.

Even the low-cost measures, energy management and cross-sector devices, make a considerable contribution to the total savings. Another advantage of these measures is that they can be implemented within a short time.

However, the greatest contributions come from improvements in process technology and the introduction of more CHP. Although these measures are mostly linked with high investments they will often be cost effective. The disadvantage is that these measures need more time to be introduced, because some of them are to be integrated into new or retrofitted plants. This means waiting until the end of the lifetime of an installation.

IV.3.2 Process technology

Upgrading processes gives the most energy savings. Next step is to know how to measure the state of art and to decide on the potential improvements. One approach to this is pinch technology. Pinch technology is abstract enough to be incorporated into legislation, but variable enough to be applied across different sectors.

In thermodynamic methodology, all processes are checked whether they are operating at optimum. This approach, together with a benchmark system, could be an effective tool to monitor, regulate and improve energy efficiency, and to investigate the best techniques and the best processes. The advantage is that a common basic approach is used for the same processes, resulting in comparable data. This makes it possible to set limits for a specific production line, for example in the form of GJ per produced ton of steel. The process that uses the lowest amount of energy could be declared as the best technology. Once these best techniques have been identified, it is then possible to say that all other industries have to aim to reach this standard in a specified period of time. The Italian environmental authority has already tested pinch technology successfully.

Pinch technology can be a practical instrument to monitor, supervise, regulate and improve energy efficiency, especially if combined with a benchmark system.

IV.3.3 Combined heat and power (CHP)

Combined heat and power, also known as co-generation, is the simultaneous production of heat and power in one process. As the heat is used sensibly (in the form of hot water or steam as an energy source in the production process or fed into a district heating network), the overall efficiency can reach 90 % when state of the art technologies are used. In contrast, conventional plants operating in the condensing mode can only achieve a maximum efficiency of 40 %, or if combined cycle gas turbine plants (CCGT) are used, 58 %. However, CHP technology is marginal in some EU countries.

Because of the high investments for CHP, the figures shown in Table IV.2 are to be seen as a technical potential. This means that it is technically possible to reach these savings, but the assumption is that all existing plants are altered to be state of the art plants. It is important to note that CHP plants only contribute to improved energy efficiency if they are operated in the back pressure mode. This means that the produced heat must really be used. If not, a conventional plant would suffice, because all heat is transferred to a conventional cooling system. Especially older CHP plants would even be less efficient than a modern condensing mode plant that releases all heat to the environment. Releasing heat to the environment is the greatest problem of large CHP plants. As these plants are centralised power producers, there is a need for a long-distance heating network, which increases the heat losses. Such a network is also quite expensive. These factors lead to problems in installing new heating networks. Nevertheless, with some effort it is possible to install networks and operate them efficiently, as, for example, the city of Helsinki does. Helsinki operates one of the largest and most efficient district heating networks in the EU.

The most economical way to use the potential of CHP is to install multiple small-scaled units that are situated close to potential customers. In turn, these units have a need for better environmental protection systems, as the most capable ones are presently only available at moderate costs for large-scale plants. By making such techniques cost-effective (e.g. granting subsidies), the potential of CHP would be realised.

As the demand for electricity is higher than for heat there will always be unused waste heat. To improve on this it is possible to install small-scaled units in a sector’s industries with a high heat demand; the excess electricity can be fed into the municipal grid. This also results in a higher total efficiency. The technical potential of CHP can improve energy efficiency considerably.

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