Berlin, 22 February 2007

# An analysis of the national potential for the application of high-efficiency cogeneration, including high-efficiency micro-cogeneration in Germany

Report as per Article 6(1) and (2) of Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market

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**List of abbreviations**

# List of abbreviations

| | |
|---|---|
| ABL | Old Federal Länder |
| AGFW | The German Heat and Power Association at the Bremer Energy Institute |
| BHKW | Block-type thermal power station |
| BMWA | Federal Ministry of Labour and Economic Affairs |
| BMWi | Federal Ministry of Economic Affairs and Technology |
| DLR | German Aerospace Centre |
| EEG | Renewable Energies Act |
| EFH | Single-family house |
| el | Electrical |
| EZFH | Single-family and semi-detached houses |
| FW | District heating |
| GD | Counter pressure |
| GHD | Tertiary sector |
| GLKE | Gas pipeline cost benefit |
| GT | Gas turbine |
| HKW | Combined heating and power station |
| KWK | Cogeneration |
| KWKG | Cogeneration Act |
| KWKK | Combined heat, cold and power supply |
| KE | Condensation removal |
| MFH | Multiple family dwelling |
| NaWaRo | Renewable raw materials |
| NBL | New Federal Länder |
| NWG | Non-residential building |
| PE | Primary energy |
| RDH | Terraced houses and pairs of semi-detached houses |
| ST | Settlement type |
| th | Thermal |
| WE | Accommodation unit |

# 0. Preliminary remark

The report analysing the national potential for the application of high-efficiency cogeneration, including high-efficiency micro-cogeneration, is based on a study of the same name commissioned at the Bremer Energy Institute by the Federal Ministry of Economic Affairs and Technology, and which summarises the principal statements contained therein.

The study compiled by the Bremer Energy Institute was presented to the general public in the middle of 2006 within the framework of a presentation. Excerpts from the study have also already been published in technical journals.

# 1. Energy industry environment in Germany

## 1.1 Primary energy use and reserves of energy resources

Table 1-1 shows primary energy consumption in Germany in 2004 [Federal Ministry of Economic Affairs and Technology, 2005]. Fig. 1-1 clarifies the shares of the individual energy resources.

**Table 1-1: Primary energy consumption in Germany in 2004**

| Energy resource | Consumption [PJ] |
|---|---|
| Mineral oil | 5 214 |
| Hard coal | 1 940 |
| Brown coal | 1 647 |
| Natural gases (natural gas, petroleum gas, mine gas) | 3 280 |
| Nuclear energy | 1 823 |
| Water and wind power | 164 |
| Other (including biomass) | 340 |
| **Total consumption** | **14 408** |

[Key to diagram:
Wasser- und Windkraft = water and wind power
Sonstige = other
Kernenergie = nuclear energy
Mineralöl = mineral oil
Naturgase = natural gases
Braunkohle = brown coal
Steinkohle = hard coal]

**Fig. 1-1: Shares of energy resources making up primary energy consumption in Germany in 2004**

The energy resources used have to be imported for the most part, as is demonstrated by the breakdown of net import quotas in Table 1-2 [Federal Ministry of Economic Affairs and Technology, 2005]. The only exception is brown coal - here, a negative import quota value even indicates a slight export surplus.

**Table 1-2: Net imports of primary energy into Germany in 2004**

| Energy resource | Net import quota[1] [%] |
|---|---|
| Mineral oil | 96.1 |
| Hard coal | 60.7 |
| Brown coal | - 0.7 |
| Natural gases (natural gas, petroleum gas, mine gas) | 83.2 |
| Nuclear energy | 100.0 |
| **Total** | **74.4** |

[1] Share of primary energy consumption accounted for by the sum of imports minus exports and bunkers

Compared to global reserves, reserves of energy resources in Germany are very limited. Reserves of energy resources in Germany for 2003 are shown in Table 1-3 [Federal Ministry of Economic Affairs and Technology, 2005].

**Table 1-3: Reserves of energy resources in Germany in 2003 and the period of time they are expected to last**

| Energy resource | Reserves | Proportion of global reserves [%] | Coverage |
|---|---|---|---|
| Petroleum | 54 million tonnes | 0.0% | 14 years |
| Natural gas | 293 billion $m^3$ | 0.2% | 13 years |
| Hard coal and brown coal | 13 billion tonnes of hard coal equivalent | 1.9% | 155 years |

## 1.2 Electricity production and consumption in Germany

Table 1-4 shows which energy resources were used for producing electricity in Germany in 2003 [Federal Ministry of Economic Affairs and Technology, 2005].

The share of nuclear energy has fallen slightly over recent years, but still nevertheless accounts for almost exactly one third.

The quantities of brown and hard coal are also very significant. Together, these account for ca. 52%.

The proportions of all the other energy resources are just in single digits. However, the proportion of natural gas and renewable energy resources should rise in future.

**Table 1-4: The use of energy resources for producing electricity in Germany in 2003**

| Energy resource | Use [PJ] | Share [%] |
|---|---|---|
| Nuclear energy | 1 802 | 32.9 |
| Brown coal | 1 539 | 28.1 |
| Hard coal | 1 298 | 23.7 |
| Natural gas | 410 | 7.5 |
| Water / wind power | 158 | 2.9 |
| Other gases | 100 | 1.8 |
| Other solid fuels | 91 | 1.7 |
| Fuel oil | 73 | 1.3 |
| **Total** | **5 471** | **100.0** |

In 2003, gross electricity production in Germany stood at 642.7 TWh [terawatt hours] Table 1-5 shows details of the amount of electricity and its use in 2003 [Stachus, 2005].

**Table 1-5: Sources and use of electricity in Germany in 2003**

| | **2003 [TWh]** | **2003 [%]** |
|---|---|---|
| Gross production | | |
| - General supply | 526.8 | 82.0% |
| - Private | 21.2 | 3.3% |
| - Trade and industry | 49 | 7.6% |
| Imports | 45.7 | 7.1% |
| **Total amount** | **642.7** | **100.0%** |
| Consumption, incl. network losses | 545.3 | 84.8% |
| Power stations' own consumption | 36.6 | 5.7% |
| Pump consumption | 7.0 | 1.1% |
| Exports | 53.8 | 8.4% |
| **Total amount used** | **642.7** | **100.0**% |

Fig. 1-2 clarifies the breakdown of domestic electricity consumption (i.e. excluding exports of electricity) in 2003 (527.6 TWh) [Geiger et al., 2005]. Just under half of the electricity (242.0 TWh) is used by trade and industry.

[Key to diagram:
Öffentliche Einrichtungen = public institutions
Verkehr = transport
Landschaft = agriculture
Pumpspeicher = pumped (hydro) storage
Handel, Gewerbe = trade and commerce
Industrie und Gewerbe = trade and industry
Haushalte = households
Angaben in TWh = figures in TWh]

**Fig. 1-2: Breakdown of domestic electricity consumption in Germany in 2003**

## 1.3 Heat production and consumption in Germany

Table 1-6 subdivides final energy consumption for thermal applications in Germany in 2003 [Federal Ministry of Economic Affairs and Technology, 2005]. Oil and natural gas predominate among those energy resources used.

**Table 1-6: Final energy consumption for thermal applications in Germany in 2003**

| **Thermal application and energy resource** | **Final energy 2003 [PJ]** | | | | |
|---|---|---|---|---|---|
| | **Households** | **Industry** | **Tertiary sector** | **Transport** | **Total** |
| **Space heating** | **2 096** | **220** | **698** | **12** | **3 025** |
| - of which oil | 703 | 64 | 220 | 9 | **996** |
| - of which gas | 947 | 117 | 340 | 0 | **1 404** |
| - of which electricity | 88 | 3 | 38 | 3 | **132** |
| - of which district heating | 147 | 29 | 91 | 0 | **267** |
| - of which coal | 26 | 6 | 9 | 0 | **41** |
| - of which other | 185 | 0 | 0 | 0 | **185** |
| **Hot water** | **317** | **18** | **155** | **0** | **489** |
| **Process heat** | **117** | **1 512** | **234** | **0** | **1 864** |
| - of which oil | 0 | 120 | 50 | 0 | 170 |

| | | | | | |
|---|---|---|---|---|---|
| - of which gas | 18 | 774 | 123 | 0 | 914 |
| - of which electricity | 94 | 193 | 59 | 0 | 346 |
| - of which district heating | 0 | 32 | 0 | 0 | 32 |
| - of which coal | 0 | 378 | 0 | 0 | 378 |
| - of which other | 6 | 15 | 3 | 0 | 23 |
| **Total** | **2 529** | **1 750** | **1 087** | **12** | **5 378** |

As is demonstrated by Fig. 1-3, demand for space heating dominates the types of application. Private households consume almost half of the heat, while industry and the tertiary sector account for roughly one third and one fifth respectively. The transport sector is negligible in this regard.

[Key to diagram:
Anteile der Anwendungsarten = relative share of the types of application
Prozesswärme = process heat
Raumwärme = space heating
Warmwasser = hot water
Anteile der Sektoren = relative share of the sectors
GHD = tertiary sector
Verkehr = transport
Haushalte = households
Industrie = industry]

**Fig. 1-3: Breakdown of heat consumption in Germany in 2003**

Table 1-7 indicates the shares occupied by the areas of application in the individual sectors. While space heating accounts for the largest share in the case of private households and the tertiary sector, in the industrial sector, process heat is decisive. As far as this report is concerned, the transport sector is not important.

**Table 1-7: Thermal applications by sector in Germany in 2003**

| Area of application | Households | Industry | Tertiary sector | Transport |
|---|---|---|---|---|
| Space heating | 82.9% | 12.6% | 64.2% | 100.0% |
| Hot water | 12.5% | 1.0% | 14.3% | 0.0% |
| Process heat | 4.6% | 86.4% | 21.6% | 0.0% |
| **Total** | **100.0%** | **100.0%** | **100.0%** | **100.0%** |

### 1.4 The position of cogeneration in Germany

In connection with a drastic drop in the price of electricity, the liberalisation of the markets for grid-bound energies which took place in Germany in 1998 resulted in a massive deterioration in the economic situation of cogeneration, following which electricity production in cogeneration plants declined and cogeneration plants were decommissioned.

In the context of measures for achieving the climate protection obligations entered into, cogeneration was accorded a decisive role which was reflected in the "Agreement between the Government of the Federal Republic of Germany and German industry and commerce on reducing $CO_2$ emissions and promotion in addition to the Climate agreement dated 9 November 2000", as well as in the Cogeneration Act.

The energy industry especially committed to achieving a reduction in emissions by a total of up to 45 million tonnes of $CO_2$/yr by 2010. This contribution is to be achieved by maintaining, modernising and extending cogeneration plants, including small block-type thermal power stations, and the introduction onto the market of fuel cells with a reduction target (base year 1998) of, all told, as much as 23 million tonnes of $CO_2$/yr but, in any event, no less than 20 million tonnes of $CO_2$/yr, by 2010.

In addition, $CO_2$ is to be reduced by up to 25 million tonnes of $CO_2$/yr in 2010 by means of other measures.

The aim set out in Section 1(1) of the Cogeneration Act, which entered into force in this context on 1 April 2002, is worded as follows:

*"By 2005, a reduction in annual carbon dioxide emissions in the Federal Republic of Germany in the order of 10 million tonnes and, by 2010, of up to 23 millions all told, but at least 20 million tonnes, is to be achieved compared with the 1998 base year through the use of cogeneration. "*

Since the entry into force of the Cogeneration Act, a total of 12 685 installations have been approved as cogeneration plants by the Federal Office of Economics and Export Control up to 30 April 2006. Of these, however, 95% are small plants with a capacity of up to 2 $MW_{el}$.

The figures for cogeneration production in Germany, which have been recorded for 2003 and forwarded to Eurostat by the Federal Statistical Office, are presented in Table 1-8. The figures relate to pure production of electricity from cogeneration, thereby satisfying the criteria set out in CWA 45547. The production of electricity from cogeneration thus contributes to 12% of electricity production in Germany.

**Table 1-8: Cogeneration production in Germany in 2003 according to the report sent to Eurostat by the Federal Statistical Office**

| Cogeneration technology | Plant capacity in terms of cogeneration | | Cogeneration production | | Fuel use | Number of plants |
|---|---|---|---|---|---|---|
| **2003** | $MW_{el}$ | $MW_{th}$ | $TWh_{el}$ | $TWh_{th}$ | $TWh_{Br}$ | |
| Combined cycle power station | 2 606 | 4 267 | 11.0 | 14.5 | 29.4 | 49 |
| Gas turbine | 2 003 | 3 813 | 7.4 | 14.9 | 25.9 | 166 |
| Block-type thermal power station | 727 | 1 063 | 2.4 | 3.7 | 7.7 | 632 |
| Counter pressure turbine | 13 909 | 36 222 | 32.2 | 111.0 | 184.5 | 580 |
| Other | 1 957 | 4 474 | 5.3 | 10.8 | 19.5 | 14 |
| **Total** | **21 202** | **49 839** | **58.4** | **155.0** | **267.1** | **1 441** |

The data contained in Table 1-8 only relates to block-type thermal power stations with a plant capacity in excess of 2 $MW_{el}$. The cogeneration production of extraction condensing turbines should be included in the column "Counter pressure turbines".

It is clear from the data provided by the Federal Statistical Office that in 2003, the particularly efficient combined cycle power stations produced 19% of the electricity from cogeneration. Against the background of the cogeneration potential determined, in which this technology plays a decisive role, this represents a modest base level.

The average power-to-heat ratio of 0.38 which emerges from Table 1-9 shows that, among the existing cogeneration plants, significant reserves are still available for improving the power-to-heat ratio.

**Table 1-9: Electrical utilisation ratios and power-to-heat ratios of cogeneration technologies in Germany in 2003, calculated according to the report sent to Eurostat by the Federal Statistical Office**

| | Utilisation ratios | | Power-to-heat ratio |
|---|---|---|---|
| **2003** | **electrical** | **altogether** | |
| Combined cycle power station | 38% | 87% | 0.76 |
| Gas turbine | 29% | 86% | 0.50 |
| Block-type thermal power station | 32% | 80% | 0.65 |
| Counter pressure turbine | 17% | 78% | 0.29 |
| Other | 27% | 83% | 0.49 |
| **Total** | **22%** | **80%** | **0.38** |

A power-to-heat ratio of 1.12 would result when realising the district heating cogeneration potential which is considered cost-efficient. This means that at many locations, the production of electricity from cogeneration can be expanded considerably without having to change anything as regards the amount of heat sold.

If the production of heat from cogeneration pursuant to Table 1-8 was to be carried out in plants which had been optimised accordingly, the impact of this alone would increase the production of electricity from cogeneration from 58 TWh/yr in 2003 to 174 TWh/yr. In this regard, consideration has still not been given to the fact that plants with capacities of less than 2 $MW_{el}$ are combined with further heat production from cogeneration plants and that the configuration of cogeneration plant and steam generator or boiler is frequently not as good as it could be, meaning that a further increase in cogeneration production would be possible in this area.

Pursuant to Table 1-10, the energy resource which is best suited within the framework of determining potential, natural gas, has thus far accounted for 43% of the cogeneration production base. Apart from other existing energy tapping from large power stations which use hard coal or brown coal, waste incineration, gases from production processes and biomass, production from this aspect should still largely switch to natural gas.

**Table 1-10: Fuel use in cogeneration plants in 2003 according to the report sent to Eurostat by the Federal Statistical Office**

| Fuel used in cogeneration (2003) | Public producers [TJ] | Independent producers [TJ] | Proportion of fuel |
|---|---|---|---|
| Hard coal | 208 547 | 57 838 | 28% |
| Brown coal | 67 991 | 32 296 | 10% |
| Heavy oil | 370 | 24 685 | 3% |
| Diesel | 4 909 | 2 985 | 1% |
| Natural gas | 176 142 | 239 853 | 43% |
| Refinery gas | 0 | 7 976 | 1% |
| Coke oven gas | 0 | 3 130 | 0% |
| Blast furnace gas | 547 | 6 310 | 1% |
| REG | 14 807 | 21 697 | 4% |
| Other | 17 547 | 73 760 | 9% |
| **Total** | **490 860** | **470 530** | **100%** |
| Gross electricity production (GW) | 34 911 | 23 513 | |
| Net heat production (TJ) | 262 937 | 295 108 | |

The data collected in relation to the 737 individual plants in 2004 by the Federal Office of Economics and Export Control within the framework of cogeneration certification offers a detailed insight. With a figure of at least 61.6 $TWh_{el}$/yr (given the lack of data, a few plants are not yet included in this total), the total amount of electricity produced from cogeneration is slightly higher than the total quantity indicated above for 2003. This at least points away from the trend that cogeneration production had to increase between 2003 and 2004, in which connection no direct comparison could be made between the data provided by the Federal Office of Economics and Export Control and that provided by the Federal Statistical Office. Growth is almost entirely limited to those plants operated with natural gas. Here, therefore, a clear trend in the direction of natural gas is being recorded.

### 1.4.1 Assessment of the stock of installations against the background of the criterion of high efficiency as defined in Directive 2004/8/EC

The question has been investigated as to the extent to which existing plants already satisfy the criterion of high efficiency as laid down in the Cogeneration Directive 2004/8/EC. It is satisfied if the primary energy savings for cogeneration plants > 1 $MW_{el}$ are at least 10% vis-à-vis a reference system for separate production. According to the Directive, for comparison purposes, the most efficient separate production systems which are available at the time of construction shall be used, taking account of identical energy resources. Corresponding matrices for reference systems are drawn up within the framework of a mandate from the EU Commission [Draft Matrix, 2005]. Taking into account the situation as at December 2005 regarding the establishment of corresponding reference values, the following picture emerges (on the basis of 737 plants):

- 86% of the production of electricity from cogeneration satisfies the criterion of high efficiency,
- 70% of the production of heat from cogeneration satisfies the criterion of high efficiency.

As regards those plants operating exclusively with natural gas which make up the majority in terms of numbers, the proportions of highly efficient plants are roughly the same. To prevent problems of corrosion, plants based on waste incineration have low steam temperatures and pressures and, for this reason, only have low overall utilisation ratios in the region of 60%. Taking this low value into account, the criterion of high efficiency is satisfied by a figure of 55% for electricity and 38% for heat. New plants which are powered by natural gas do not have any problem fulfilling the efficiency criterion.

### 1.4.2 Assessment of the ability to develop existing cogeneration production in Germany

At this point, the question must be posed as to the area in which the possibility of raising the ratio of electrical utilisation and, hence, the power-to-heat ratios as well, should primarily occur. Table 1-11 shows a breakdown of utilisation ratios for electricity produced by cogeneration as determined on the basis of data provided by the Federal Office of Economics and Export Control according to performance classes (the largest proportions each time are highlighted in the table in colour).

The values specified each time indicate the proportion to which the net quantity of electricity produced from cogeneration in a utilisation ratio class corresponds in terms of the total quantity of electricity produced in this performance class. This is more meaningful than a proportion which only relates to the number of plants.

**Table 1-11: Analysis of data provided by the Federal Office of Economics and Export Control for 2004 regarding the distribution of utilisation ratios for electricity from cogeneration between performance classes**

| Utilisation ratios for electricity from cogeneration Performance class | below 10% | 10.1 - 15% | 15.1 - 20% | 20.1 - 25% | 25.1 - 30% | 30.1 - 35% | 35.1 - 40% | 40.1 - 45% | 45.1 - 50% | above 50% | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| up to 5 $MW_{el}$ | 6% | 3% | 2% | 10% | 16% | 31% | 28% | 2% | 1% | 1% | 100% |
| 5.01 - 10 $MW_{el}$ | 9% | 10% | 10% | 12% | 16% | 15% | 24% | 5% | 0% | 0% | 100% |
| 10.01 - 20 $MW_{el}$ | 5% | 11% | 16% | 23% | 17% | 13% | 13% | 3% | 0% | 0% | 100% |
| 20.01 - 30 $MW_{el}$ | 3% | 24% | 23% | 12% | 13% | 19% | 4% | 4% | 0% | 0% | 100% |
| 30.01 - 40 $MW_{el}$ | 5% | 2% | 33% | 19% | 31% | 10% | 0% | 0% | 0% | 0% | 100% |
| 40.01 - 50 $MW_{el}$ | 8% | 10% | 24% | 22% | 9% | 0% | 27% | 0% | 0% | 0% | 100% |
| 50.01 - 100 $MW_{el}$ | 2% | 4% | 15% | 8% | 20% | 29% | 4% | 9% | 8% | 0% | 100% |
| 100.1 - 200 $MW_{el}$ | 0% | 0% | 13% | 22% | 7% | 9% | 20% | 16% | 3% | 9% | 100% |
| in excess of 200 $MW_{el}$ | 0% | 0% | 0% | 12% | 23% | 13% | 15% | 22% | 12% | 3% | 100% |

It becomes clear that plants with a reasonable cogeneration efficiency largely exist in all performance classes up to 100 $MW_{el}$. Plants up to 10 $MW_{el}$ and large plants still have a relatively advantageous distribution of electrical utilisation ratios.

The range from 10 to 50 $MW_{el}$ is rather more problematic. This becomes especially clear in Table 1-12 where the proportions given in Table 1-11 are added up (proportions which exceed 50% for the first time are again marked in colour). Without going into the special framework conditions which the individual plants are subject to, it can be determined that considerable additional cogeneration potential can be exploited by replacing just a small number of inefficient plants.

**Table 1-12: Analysis of data provided by the Federal Office of Economics and Export Control for 2004 regarding the distribution of utilisation ratios for electricity from cogeneration between performance classes (cumulative)**

| Utilisation ratios for electricity from cogeneration Performance class | below 10% | 10.1 - 15% | 15.1 - 20% | 20.1 - 25% | 25.1 - 30% | 30.1 - 35% | 35.1 - 40% | 40.1 - 45% | 45.1 - 50% | above 50% |
|---|---|---|---|---|---|---|---|---|---|---|
| up to 5 $MW_{el}$ | 6% | 9% | 12% | 22% | 38% | 69% | 96% | 98% | 99% | 100% |
| 5.01 - 10 $MW_{el}$ | 9% | 19% | 29% | 41% | 57% | 72% | 95% | 100% | 100% | 100% |
| 10.01 - 20 $MW_{el}$ | 5% | 16% | 32% | 54% | 72% | 85% | 97% | 100% | 100% | 100% |
| 20.01 - 30 $MW_{el}$ | 3% | 27% | 49% | 61% | 74% | 92% | 96% | 100% | 100% | 100% |
| 30.01 - 40 $MW_{el}$ | 5% | 6% | 40% | 59% | 90% | 100% | 100% | 100% | 100% | 100% |
| 40.01 - 50 $MW_{el}$ | 8% | 18% | 42% | 63% | 73% | 73% | 100% | 100% | 100% | 100% |
| 50.01 - 100 $MW_{el}$ | 2% | 6% | 21% | 29% | 50% | 78% | 83% | 91% | 100% | 100% |
| 100.1 - 200 $MW_{el}$ | 0% | 0% | 13% | 35% | 43% | 52% | 72% | 87% | 91% | 100% |
| in excess of 200 $MW_{el}$ | 0% | 0% | 0% | 12% | 35% | 48% | 63% | 85% | 97% | 100% |

Consideration must also be given to the fact that the utilisation ratio distribution depends on the main fuel.

A low electricity utilisation ratio is anticipated in relation to waste incineration as determined by the system. It follows from Table 1-13, however, that those plants which are also powered with fuel oil are largely situated in the unfavourable range. Distribution clearly turns out the best in the case of cogeneration based on natural gas. Replacing coal and fuel oil with natural gas would therefore bring about a considerable improvement in utilisation ratios for electricity from cogeneration. The proportions are calculated in a similar way to the analysis of the performance classes, i.e. with regard to the quantities of electricity produced from cogeneration relative to the total quantity produced in a performance class.

**Table 1-13: Analysis of data provided by the Federal Office of Economics and Export Control for 2004 regarding the distribution of utilisation ratios for electricity from cogeneration between fuel types**

| Utilisation ratios for electricity from cogeneration | below 10% | 10.1 - 15% | 15.1 - 20% | 20.1 - 25% | 25.1 - 30% | 30.1 - 35% | 35.1 - 40% | 40.1 - 45% | 45.1 - 50% | above 50% | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hard coal | 1% | 3% | 12% | 31% | 35% | 12% | 5% | 0% | 0% | 0% | 100% |
| Brown coal | 3% | 4% | 36% | 11% | 21% | 15% | 9% | 0% | 0% | 1% | 100% |
| Natural gas | 1% | 3% | 5% | 9% | 9% | 18% | 20% | 20% | 10% | 5% | 100% |
| Fuel oil | 0% | 27% | 31% | 0% | 1% | 2% | 3% | 36% | 0% | 0% | 100% |
| Waste incineration | 51% | 45% | 2% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

### 1.4.3 Combined heat, cold and power supply (CHCP)

In the Cogeneration Directive 2004/8/EC, cold production by means of the heat produced in cogeneration plants is specifically mentioned as a useful field of application for cogeneration.

Since the absorption refrigerators which are largely used to this end have a substantially lower performance ratio (energy input to cold production) than compression-type refrigerating machines, however, the primary energy advantage is generally low.

The economic assessment also depends on many factors which cannot be generalised.

If the production base involves a waste incinerating plant, the prospects for cogeneration plants are good because this form of production would run at full capacity all-year round in any case. If, however, a relatively small plant is to be supplied with heat for cold production within the framework of a district heating grid and, to this end, the district heating temperature has to be kept at a high level even in summer, unfavourable efficiency must tend to be assumed.

Given the existing diversity, this technology has escaped a systematic analysis of its potential for Germany. It is also assumed that the potential which exists in this country is relatively small compared to the heat requirement coverage from cogeneration plants. In the context of the on-going preparation of an instruction for the Cogeneration Directive, the drawing up of reference efficiency values for the separate production of electricity and cold has been dispensed with. One reason for this is that the primary energy advantage which can be achieved using this technology can be classified as slight. Hence, within the framework of the analysis of cogeneration potential across the country, the cogeneration plants are not considered from the point of view of data.

### 1.5 Forecast trends in the energy market up to 2030

Energy Report IV, 2005, makes forecasts regarding the development of the national energy market up to the year 2030. Fig. 1-4 shows that overall, a slight drop in energy consumption of around 8% is anticipated between 2002 and 2030 according to EWI/Prognos.

Only the proportion of electricity in final energy consumption will increase slightly. Table 1-14 reproduces the other individual figures and the trend across the different sectors.

[Key to diagram:
Endenergieverbrauch = final energy consumption
Öl = oil
Gas = gas
Steinkohle = hard coal
Braunkohle = brown coal
Strom = electricity
Fernwärme = district heating
Regenerative = renewables]

**Fig. 1-4: Forecast of final energy consumption according to energy resources**

**Table 1-14: Forecast of final energy consumption according to energy resources and sectors (data in PJ/yr)**

| According to energy resources | 1995 | 2000 | 2002 | 2010 | 2015 | 2020 | 2025 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Hard coal | 455 | 407 | 355 | 341 | 319 | 305 | 293 | 287 |
| Brown coal | 178 | 80 | 77 | 55 | 49 | 41 | 41 | 42 |
| Mineral oil products | 4 402 | 4 171 | 4 046 | 4 014 | 3 862 | 3 628 | 3 481 | 3 337 |
| *Light fuel oil* | *1 436* | *1 174* | *1 166* | *1 170* | *1 079* | *991* | *925* | *863* |
| *Heavy fuel oil* | *157* | *105* | *100* | *97* | *95* | *91* | *88* | *85* |
| *Petrol* | *1 321* | *1 254* | *1 180* | *827* | *670* | *557* | *507* | *466* |
| *Diesel, aviation fuel* | *1 374* | *1 551* | *1 524* | *1 835* | *1 938* | *1 916* | *1 896* | *1 860* |
| *Other mineral oil products* | *114* | *88* | *76* | *84* | *79* | *72* | *65* | *63* |
| Gas | 2 163 | 2 305 | 2 401 | 2 414 | 2 379 | 2 329 | 2 267 | 2 214 |
| *Natural gas* | *2 025* | *2 172* | *2 278* | *2 307* | *2 280* | *2 237* | *2 182* | *2 132* |
| *Other gases* | *139* | *133* | *123* | *106* | *99* | *92* | *85* | *81* |
| Renewable energies | 110 | 211 | 229 | 278 | 323 | *372* | 405 | 429 |
| Electricity | 1 648 | 1 738 | 1 781 | 1 855 | 1 874 | 1 876 | 1 869 | 1 855 |
| District heating | 366 | 328 | 335 | 319 | 308 | 296 | 279 | 262 |

| In total | 9 322 | 9 241 | 9 225 | 9 275 | 9 116 | 8 847 | 8 636 | 8 427 |
|---|---|---|---|---|---|---|---|---|
| according to consumption sectors | | | | | | | | |
| Private households | 2 655 | 2 602 | 2 699 | 2 797 | 2 730 | 2 640 | 2 553 | 2 470 |
| Tertiary sector | 1 579 | 1 477 | 1 518 | 1 480 | 1 424 | 1 357 | 1 279 | 1 204 |
| Industry | 2 474 | 2 411 | 2 334 | 2 312 | 2 272 | 2 228 | 2 195 | 2 177 |
| Transport | 2 614 | 2 751 | 2 673 | 2 686 | 2 689 | 2 622 | 2 609 | 2 576 |
| **Structure as a %** | **1995** | **2000** | **2002** | **2010** | **2015** | **2020** | **2025** | **2030** |
| Hard coal | 4.9 | 4.4 | 3.9 | 3.7 | 3.5 | 3.4 | 3.4 | 3.4 |
| Brown coal | 1.9 | 0.9 | 0.8 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 |
| Mineral oil products | 47.2 | 45.1 | 43.9 | 43.3 | 42.4 | 41.0 | 40.3 | 39.6 |
| *Light fuel oil* | *15.4* | *12 7* | *12.6* | *12.6* | *11.8* | *11.2* | *10.7* | *10.2* |
| *Heavy fuel oil* | *1.7* | *1.1* | *1.1* | *1.1* | *1.0* | *1.0* | *1.0* | *1.0* |
| *Petrol* | *14.2* | *13.6* | *12.8* | *8.9* | *7.4* | *6.3* | *5.9* | *5.5* |
| *Diesel, aviation fuel* | *14.7* | *16.8* | *16.5* | *19.8* | *21.3* | *21.7* | *22.0* | *22.1* |
| *Other mineral oil products* | *1.2* | *1.0* | *0.8* | *0.9* | *0.9* | *0.8* | *0.8* | *0.7* |
| Gas | 23.2 | 24.9 | 26.0 | 26.0 | 26.1 | 26.3 | 26.3 | 26.3 |
| *Natural gas* | *21.7* | *23.5* | *24.7* | *24.9* | *25.0* | *25.3* | *25.3* | *25.3* |
| *Other gases* | *1.5* | *1.4* | *1.3* | *1.1* | *1.1* | *1.0* | *1.0* | *1.0* |
| Renewable energies | 1.2 | 2.3 | 2.5 | 3.0 | 3.5 | 4.2 | 4.7 | 5.1 |
| Electricity | 17.7 | 18.8 | 19.3 | 20.0 | 20.6 | 21.2 | 21.6 | 22.0 |
| District heating | 3.9 | 3.5 | 3.6 | 3.4 | 3.4 | 3.3 | 3.2 | 3.1 |
| **In total** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** |
| According to consumption sectors | | | | | | | | |
| Private households | 28.5 | 28.2 | 29.3 | 30.2 | 29.9 | 29.8 | 29.6 | 29.3 |
| Tertiary sector | 16.9 | 16.0 | 16.5 | 16.0 | 15.6 | 15.3 | 14.8 | 14.3 |
| Industry | 26.5 | 26.1 | 25.3 | 24.9 | 24.9 | 25.2 | 25.4 | 25.8 |
| Transport | 28.0 | 29.8 | 29.0 | 29.0 | 29.5 | 29.6 | 30.2 | 30.6 |

Source: *AG Energiebilanzen e.V.*, *EWI/Prognos* and calculations carried out by the Bremer Energy Institute

## 2. Cogeneration potential in Germany

EU Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market entered into force on 21 February 2004. According to Article 6, Member States must publish an analysis of the national potential for the application of high-efficiency cogeneration. This development corresponds to the version of the guideline for preparing studies regarding potential from November 2005 [Draft Guideline, 2005].

A technique by means of which a primary energy saving of 10% can be achieved in relation to separate electricity and heat production is regarded as high-efficiency cogeneration. Plants with a capacity of up to 1 $MW_{el}$ are always regarded as highly efficient if primary energy savings are produced. Reference values for separate electricity and heat production using the best available technology each time which is operated in practice are consulted as a benchmark for primary energy savings.

For methodical reasons, the following part potentials were drawn up, separated into fields of application:

- the potential for supplying grid-bound district heating to residential buildings and the tertiary sector
- the potential for small-scale cogeneration in residential buildings relative to the property

- the potential for small-scale cogeneration in non-residential buildings
- the potential for industrial cogeneration
- the potential for cogeneration as a result of using biomass.

When estimating this potential, assessments are made, inter alia, of the primary energy and $CO_2$ savings, the electricity and heat produced from cogeneration, and of the investment required. Partial results are summarised below. The socio-economic framework conditions which are taken as a basis follow, where possible, Energy Report IV [2005].

The potential is calculated by an economic appraisal which includes two levels of consideration each time:

- Macroeconomic approach: rate of interest: 5%/yr,
- Microeconomic approach: rate of interest: 8%/yr.

As regards the trend in energy resource prices, three price scenarios are analysed in both approaches:

- a lower price scenario which is guided by Energy Report IV, 2005, and which is designated the Low Price Scenario,
- an upper price scenario where the energy supply prices are 50% higher (across the board) and which is therefore designated the High Price Scenario,
- an upper price scenario where the border crossing prices and the power station fuel prices are 100% higher and, on top of that, it is assumed that 50% of the natural gas prices incurred by final household consumers can be attributed to the costs of supplying the gas (border crossing prices), with the other 50% accounted for by the costs of the gas pipeline system, and which is therefore designated a High Price Scenario with gas pipeline cost benefit. In the case of end customers, this stipulation therefore also results in natural gas prices which are 50% higher than those under Energy Report IV.

Given the need for new power station capacity, it is assumed that new cogeneration plants must compete with the production costs incurred by new power stations. As regards the reference production costs, production in hard coal and natural gas power stations was fixed at the ratio of 1:4. (With the exception of small block-type thermal power stations), the average number of hours when new plants which produce electricity from cogeneration and reference power stations are operating at full capacity is assumed to be 4 000 h/yr. As regards these hours when the plants are operating at full capacity, the costs of producing electricity in hard coal and natural gas power stations are almost identical, meaning that the power station mix ratio which has been set plays a secondary role.

It is assumed that the release of $CO_2$ in fossil-fuelled energy conversion systems in the period under review up to 2020 will be burdened with a surcharge, probably in the region of €10/t $CO_2$.

## 2.1 District heating cogeneration potential

### 2.1.1 Current district heating supplies

In 2005, the district heating supplied (residential + tertiary) in the old Federal Länder was 54 TWh/yr and 21.5 TWh/yr in the new Federal Länder.

### 2.1.2 The development in heat demand

Table 2-1 shows how the demand for useful heat will develop in those towns which are suitable for district heating in the old and new Federal Länder in the period under review. All in all, there will just be a slight drop in the useful heat demand by 2020 (- 4.1%), and no differences worth mentioning between the old and the new Federal Länder. The savings as a result of building redevelopments are partly offset in this connection by the specific increased demand for living space per citizen.

**Table 2-1: The development of useful heat demand in towns**

| **Useful heat demand for space heating, service water used by households and the tertiary sector [TWh/yr]** | | | |
|---|---|---|---|
| **Year** | **Old Federal Länder** | **New Federal Länder** | **Total** |
| 2005 | 390.1 | 57.8 | **448.0** |
| 2010 | 382.2 | 56.3 | **438.5** |
| 2015 | 379.5 | 55.8 | **435.3** |
| 2020 | 374.7 | 55.1 | **429.8** |

Fig. 2-1 clarifies the trends in the residential building and tertiary sectors. In both cases, there will be a slight drop in the demand for heat, in which connection the reduction in the tertiary sector (-7.7% when comparing 2020 to 2005) will be greater than is the case with private households (-2.1% when comparing 2020 to 2005).

[Key to diagram:
Nutzwärmebedarf = useful heat demand
Wohnen = residences
GHD = tertiary sector]

**Fig. 2-1: The development of useful heat demand in towns**

It is established from the slight change in the demand for heat that it is not necessary to present the trend in the potential for development between 2005 and 2020 in the scenarios under consideration. This fact also fits in with the realities for possible utilisation of potential on a larger scale. In the case of grid-bound heat distribution, this potential is characterised by a longer period of pipe laying, which generally lasts several years. Likewise, replacing existing local heating installations with a district heating connection stretches to a number of years because the users will naturally utilise their existing supply facilities (depending on the respective age of the heating system) for as long as they are technically sound and can be operated economically. Consequently, the entire substitution process in large districts covers the period of the standard service life of heating installations of 10-15 years.

### 2.1.3 Economically viable potential for high-efficiency cogeneration

Significant cogeneration potential can be realised using district heating systems. According to the main report compiled by the German District Heating Association for 2003, the heat intake of a network is 323 PJ (90 TWh/yr). Corresponding to this, 35 TWh of cogeneration electricity were produced. Just by modernisation geared towards efficiency, the production of electricity from cogeneration could be increased to almost 90 TWh/yr with the same quantity of heat sold.

Further potential could be realised by concentrating connections, expanding existing networks and by opening up contiguous developing areas.

The overall economic potential which exists in the district heating sector has been determined on the basis of a detailed compartmentalisation of the towns into types of settlement and building, as well as on the basis of assigning employees in the tertiary sector ("Germany's digital heat card").

For each of the 614 towns in Germany with at least 20 000 inhabitants (or 2 000 large multiple family dwellings), individual calculations and calculations according to the type of settlement have been carried out according to the formula

District heat production costs<br>
<u>+ district heat distribution costs</u><br>
total costs — should be less than or equal to the district heating price applied because it is a question of an economic district heating cogeneration potential.

The applicable district heating price is determined by a full cost comparison with a local natural gas solution for an array of residential buildings.

The calculations also give consideration to the current district heating supply, along with the structural potential for expanding and developing district heating, which is typical of the settlement.

The indication of technical potential for the heating market sector, which is being considered in this chapter, is not possible in a meaningful manner. As regards the heat demanded, this always involves low temperature heat which, in all cases, can be provided by a cogeneration plant via a heat distribution system. Other than in the industrial sector therefore, there is no relevant share of the potential which, for technical reasons, e.g. a required temperature which is too high, should not be provided by cogeneration plants (the share of process heat required in the tertiary sector in the temperature range above 100 °C is negligibly small) and which should be supplied by other producing plants. From the purely technical viewpoint, in principle, the installation of pipes for every heat customer can also be presented.

It also remains to be established that cogeneration technology has, in the meantime, become so well established that there is virtually one installation for every heat demand which could cover this technically. Consequently, the quantity of heat at the respective place of use does not represent any limiting factor from the technical viewpoint either.

### Table 2-2: Estimating the potential (macroeconomic approach)

| **From the macroeconomic viewpoint** | **5%** | **Heat demand** | **District heating supplies** | **Potential for development** | | | **District heating not cost-efficient** |
|---|---|---|---|---|---|---|---|
| | | | | **Concentration** | **Expansion** | **Concentration + expansion = development** | |
| **High Price Scenario** | | | | | | | |
| Old Federal Länder | TWh/yr | 390.1 | 54.0 | 20.9 | 120.8 | 141.7 | 194.5 |
| | **%** | 100.0% | 13.8% | **5.4%** | 31.0% | 36.3% | 49.8% |
| New Federal Länder | TWh/yr | 57.8 | 21.5 | 0.3 | 15.0 | 15.2 | 21.1 |
| | **%** | 100.0% | 37.2% | **0.4%** | 25.9% | 26.3% | 36.5% |
| **Total** | **TWh/yr** | **448.0** | **75.5** | **21.1** | **135.8** | **156.9** | **215.6** |
| | **%** | **100.0%** | **16.9%** | **4.7%** | **30.3%** | **35.0%** | **48.1%** |
| **High Price Scenario + Gas pipeline cost benefit** | | | | | | | |
| Old Federal Länder | TWh/yr | 390.1 | 54.0 | 20.5 | 114.9 | 135.3 | 200.8 |
| | **%** | 100.0% | 13.8% | **5.2%** | 29.4% | 34.7% | 51.5% |
| New Federal Länder | TWh/yr | 57.8 | 21.5 | 0.3 | 15.2 | 15.5 | 20.8 |
| | **%** | 100.0% | 37.2% | **0.4%** | 26.3% | 26.8% | 36.0% |
| **Total** | **TWh/yr** | **448.0** | **75.5** | **20.7** | **130.1** | **150.8** | **221.6** |
| | **%** | **100.0%** | **16.9%** | **4.6%** | **29.0%** | **33.7%** | **49.5%** |
| **Low Price Scenario** | | | | | | | |
| Old Federal Länder | TWh/yr | 390.1 | 54.0 | 17.4 | 94.9 | 112.3 | 223.9 |
| | **%** | 100.0% | 13.8% | **4.5%** | 24.3% | 28.8% | 57.4% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| New Federal Länder | TWh/yr | 57.8 | 21.5 | 0.3 | 10.3 | 10.6 | 25.8 |
| | % | 100.0% | 37.2% | **0.4%** | 17.8% | 18.3% | 44.5% |
| **Total** | **TWh/yr** | **448.0** | **75.5** | **17.6** | **105.2** | **122.9** | **249.6** |
| | **%** | **100.0%** | **16.9%** | **3.9%** | **23.5%** | **27.4%** | **55.7%** |

## Table 2-3: Estimating the potential (microeconomic approach)

| **From the microeconomic viewpoint** | **8%** | **Heat demand** | **District heating supplies** | **Potential for development** | | | **District heating not cost-efficient** |
|---|---|---|---|---|---|---|---|
| | | | | **Concentration** | **Expansion** | **Concentration + expansion = development** | |
| **High Price Scenario** | | | | | | | |
| Old Federal Länder | TWh/yr | 390.1 | 54.0 | 20.6 | 108.0 | 128.6 | 207.6 |
| | % | 100.0% | 13.8% | **5.3%** | 27.7% | 33.0% | 53.2% |
| New Federal Länder | TWh/yr | 57.8 | 21.5 | 0.3 | 14.3 | 14.6 | 21.8 |
| | % | 100.0% | 37.2% | **0.4%** | 24.7% | 25.2% | 37.6% |
| **Total** | **TWh/yr** | **448.0** | **75.5** | **20.9** | **122.3** | **143.2** | **229.3** |
| | **%** | **100.0%** | **16.9%** | **4.7%** | **27.3%** | **32.0%** | **51.2%** |
| **High Price Scenario + Gas pipeline cost benefit** | | | | | | | |
| Old Federal Länder | TWh/yr | 390.1 | 54.0 | 19.9 | 97.1 | 117.0 | 219.1 |
| | % | 100.0% | 13.8% | **5.1%** | 24.9% | 30.0% | 56.2% |
| New Federal Länder | TWh/yr | 57.8 | 21.5 | 0.3 | 12.0 | 12.3 | 24.1 |
| | % | 100.0% | 37.2% | **0.4%** | 20.7% | 21.2% | 41.6% |
| **Total** | **TWh/yr** | **448.0** | **75.5** | **20.1** | **109.1** | **129.2** | **243.2** |
| | **%** | **100.0%** | **16.9%** | **4.5%** | **24.4%** | **28.9%** | **54.3%** |
| **Low Price Scenario** | | | | | | | |
| Old Federal Länder | TWh/yr | 390.1 | 54.0 | 16.8 | 76.8 | 93.6 | 242.5 |
| | % | 100.0% | 13.8% | 4.3% | 19.7% | 24.0% | 62.2% |
| New Federal Länder | TWh/yr | 57.8 | 21.5 | 0.3 | 7.2 | 7.4 | 28.9 |
| | % | 100.0% | 37.2% | 0.4% | 12.4% | 12.8% | 50.0% |
| **Total** | **TWh/yr** | **448.0** | **75.5** | **17.1** | **84.0** | **101.1** | **271.4** |
| | **%** | **100.0%** | **16.9%** | **3.8%** | **18.7%** | **22.6%** | **60.6%** |

Tables 2-2 (macroeconomic approach) and 2-3 (microeconomic approach) summarise the key results regarding the economic potential of grid-bound energy with regard to the demand in 2005.

It becomes clear that with the macroeconomic approach, the economic potential for developing the useful heat demand is in the region of 27 - 35% depending on the price scenario (which roughly corresponds to 123 - 157 TWh/yr). Under the microeconomic approach, this quantity is reduced only slightly to around 23 - 32% (which roughly corresponds to 101 - 143 TWh/yr).

As expected, the expansion of existing networks and the new development of regions make up the lion's share of this potential. The comparatively low potential in the new Federal Länder shall predominantly be achieved by concentrating connections.

According to both the macroeconomic and microeconomic approaches, higher energy resource prices have a favourable impact on potential. In the first approximation, this can be explained by the fact that in the high price scenarios, the (constant) distribution costs account for a lower proportion of district heating costs overall: the sphere of production and the comparison with the production reference system becomes increasingly dominant in the cost balance sheet.

Largely irrespective of whether the High Price Scenario or the Low Price Scenario is taken as a basis, or whether the $CO_2$ emissions will result in surcharges of €10 or 20/t $CO_2$, the following picture ultimately emerges regarding the potential for development which is considered cost-efficient (the stock is still not taken into consideration in this connection):

Table 2-4: Potential for developing district heating

| | Economic district heating potential [TWh/yr] | Electrical power [$GW_{el}$] | Electricity produced by cogeneration plants [TWh/yr] |
|---|---|---|---|
| **Macroeconomic approach (5% interest)** | | | |
| ABL | 141.7 | 37.3 | 158.3 |
| NBL | 15.2 | 3.5 | 14.6 |
| **Total** | **156.9** | **42.8** | **172.9** |
| **Microeconomic approach (8% interest)** | | | |
| ABL | 128.6 | 34.6 | 146.4 |
| NBL | 14.6 | 3.4 | 14 |
| **Total** | **143.2** | **38.0** | **160.4** |

### 2.1.4 Developing the potential for primary energy and $CO_2$ savings

Using the example of the High Price Scenario, Table 2-5 shows that considerable savings in terms of primary energy and $CO_2$ can be achieved if the economic potential for development were to be realised in full.

Table 2-5: Attainable primary energy and $CO_2$ savings (High Price Scenario)

| | Economic district heating potential [TWh/yr] | Primary energy saving (including grey energy) [TWh/yr] | $CO_2$ savings (including grey energy) [million tonnes of $CO_2$/yr] |
|---|---|---|---|
| **Macroeconomic approach (5% interest)** | | | |
| ABL | 141.7 | 100.4 | 30.7 |
| NBL | 15.2 | 10.8 | 3.3 |
| **Total** | **156.9** | **111.2** | **34.0** |
| **Microeconomic approach (8% interest)** | | | |
| ABL | 128.6 | 91.1 | 27.9 |
| NBL | 14.6 | 10.3 | 3.2 |
| **Total** | **143.2** | **101.4** | **31.1** |

### 2.1.5 Installation types and electricity production

As regards the High Price Scenario, Table 2-6 below provides evidence of the fact that a production capacity of 38.0 - 42.8 GW arises as a result of realising the economic potential of developing district heating. This order of magnitude clarifies the fact that a realisation of this cogeneration potential would have a fairly considerable impact on the composition of the generation system and at least just as big an influence on the configuration of the electrical networks and the importance of standard energies.

The resulting cost effects would naturally have repercussions for the cost-effectiveness of the potential. The size of these effects cannot be quantified in the context of this report, however.

When determining the directional distribution of the types of installation used in this connection, the following general breakdown was chosen depending on the respective heat potential of a town:

- up to 70 000 MWh/yr: block-type thermal power station,
- 70 001 - 200 000 MWh/yr: gas turbine,
- above 200 001 MWh/yr: combined cycle power station.

In this connection, only one type of installation is established for each town since no sweeping statements can be made if the heat potential of a town were to be supplied by more than one production plant. As a result, on the one hand, the number of combined cycle power stations in larger towns could increase in practice while, on the other, the town could be supplied by one plant designated here as a combined cycle power station or also by several smaller gas turbines (the same also applies to the replacement of gas turbines by block-type thermal power stations, but only to a lesser extent on account of the steeper cost curves). Naturally, certain displacements will also arise with a change in the designated quantities of installation types.

**Table 2-6: Cogeneration plant types and the balance on their electricity side (High Price Scenario)**

| | **Electrical capacity [$GW_{el}$]** | **Electricity produced by cogenerations plants [TWh/yr]** | **Plant type distribution (1 plant type per town, in all: 614 towns)** |
|---|---|---|---|
| **Macroeconomic approach (5% interest)** | | | |
| ABL | 37.3 | 158.3 | 83 BHKW, 291 GT, 134 GUD |
| NBL | **3.5** | 14.6 | 34 BHKW, 60 GT, 12 GUD |
| **Total** | **42.8** | **172.9** | **117 BHKW, 351 GT, 146 GUD** |
| **Microeconomic approach (8% interest)** | | | |
| ABL | 34.6 | 146.4 | 210 BHKW, 174 GT, 124 GUD |
| NBL | 3.4 | 14.0 | 40 BHKW, 54 GT, 12 GUD |
| **Total** | **38.0** | **160.4** | **250 BHKW, 228 GT, 136 GUD** |

One interesting aspect is the clear shift towards block-type thermal power station solutions in the old Federal Länder. This shift primarily results from the 311 small towns with their heat potential which, when considered from the macroeconomic viewpoint, is in the order of 70 000 - 100 000 MWh/yr in many cases.

### 2.1.6 Investment costs

As regards the High Price Scenario, Table 2-7 shows the sums of investment which would result in relation to cogeneration plants and the concentration and expansion of the district heating network when fully realising the potential for development.

Since the potential for consolidating existing networks is only small in the new Federal Länder compared with the old ones (here, investment is only incurred in service lines and pipes for houses), higher specific investment in the supply networks results in relation to realised heat potential than in the new Federal Länder. All told in Germany, roughly two thirds of the volume of investment is allotted to the production plants and approximately one third to heat distribution.

**Table 2-7: Investment costs when developing potential (High Price Scenario)**

| | Cogeneration plants [€ millions] | Heat distribution [€ millions] | Total [€ millions] |
|---|---|---|---|
| **Macroeconomic approach (5% interest)** | | | |
| ABL | 26 194 | 13 577 | 39 771 |
| NBL | 2 817 | 1 719 | 4 536 |
| **Total** | **29 011** | **15 296** | **44 307** |
| **Microeconomic approach (8% interest)** | | | |
| ABL | 23 775 | 12 260 | 36 035 |
| NBL | 2 694 | 1 579 | 4 273 |
| **Total** | **26 469** | **13 839** | **40 308** |

### 2.1.7 Potential for implementation up to 2020

As is proven by the development in heat demand pursuant to Table 2-8, demand will scarcely drop at all by the year 2020. Consequently, there are no genuinely relevant impacts on potential.

As regards the development in potential therefore, the only question which needs to be posed is whether the speed of development which is feasible in practice, above all, the laying of pipes, represents such a significant restricting factor in terms of implementing potential that, in principle, existing potential in an early base year of the period under consideration should not yet be declared because implementation is not possible as quickly.

As with other considerations of potential, no blanket reply can be given. Very rapid implementation is conceivable from a purely technical viewpoint. The values laid down here are therefore rather conservative so as to outline a plausible development path for implementation.

**Table 2-8: Possible path in terms of implementing potential in 2005 (High Price Scenario)**

| | | Unit | **2005** | **2010** | **2015** | **2020** |
|---|---|---|---|---|---|---|
| Economic potential | Supplies | TWh/yr | 75.5 | | | |
| | Concentration | TWh/yr | 21.1 | | | |
| | Expansion | TWh/yr | 135.8 | | | |
| | **Total** | **TWh/yr** | **232.4** | | | |
| Proportion implemented | Supplies | **%** | 70 | 90 | 100 | 100 |
| | Concentration | **%** | 0 | 40 | 70 | 100 |
| | Expansion | **%** | 0 | 60 | 85 | 100 |
| Implemented potential | Supplies | TWh/yr | 52.8 | 68.0 | 75.5 | 75.5 |
| | Concentration | TWh/yr | 0.0 | 8.4 | 14.8 | 21.1 |
| | Expansion | TWh/yr | 0.0 | 81.5 | 115.4 | 135.8 |
| | **Total** | **TWh/yr** | **52.8** | **157.9** | **205.7** | **232.4** |

Around 70% of cogeneration plants are already now regarded as being highly efficient.
Concentration is proceeding comparatively slowly because existing local heating installations are

replaced gradually when they reach the end of their service life. As regards those developing areas which are available in the area of expansion, development is naturally proceeding more quickly than is the case in existing areas. Since they do not carry so much weight in terms of quantity, however, a more differentiated description was dispensed with at this point.

### 2.2 Micro-cogeneration in house building

Small block-type thermal power stations can be realised in house building outside of district heating areas which only supply individual buildings or heating systems covering several buildings each time. Naturally, such local solutions are also possible in district heating areas. Here, a grid-bound supply regularly results in lower costs, however, meaning that such potential is not counted here (twice).

No statistics are currently available from which the extent to which such concepts have already been implemented can be established.

If adequate space is available in the furnace room, such concepts could also be implemented outside of redevelopment measures. The existing boiler may continue to be used to cover peak load periods. This therefore constitutes a potential which can be implemented rapidly.

According to the results, and from the microeconomic viewpoint, the economic efficiency limits determined are considered as follows:

- in the Low Price Scenario, with an average stock of 15 family houses (24 new builds of family houses) and corresponding heating systems,
- in both of the High Price Scenarios, with an average stock of 30 family houses (48 new builds of family houses) and corresponding heating systems.

Table 2-9 summarises the microeconomic potential. Compared to the potential which can be achieved with district heating and industrial cogeneration, this is relatively small and substantially dependent on the trend in the price of natural gas.

**Table 2-9: The microeconomic potential in terms of cogeneration in relation to micro-cogeneration plants in the residential sector [outside of district heating (potential) areas]**

| **Low Price Scenario** | **GWh/yr** | **MW** |
|---|---|---|
| Heat production in block-type thermal power stations, including peak boilers | 3 520 | 1 956 |
| Electricity production | 1 232 | 308 |
| **High Price / High Price Scenario with gas pipeline cost benefit** | **GWh/yr** | **MW** |
| Heat production in block-type thermal power stations, including 1 peak boiler | 1 151 | 639 |
| Electricity production | 403 | 101 |

From the macroeconomic viewpoint, no economically portrayable potential results for micro-cogeneration plants with a capacity of up to 50 $kW_{el}$.

**Table 2-10: The extent of investment costs, primary energy savings and $CO_2$ reductions for cogeneration solutions in the residential building sector relative to the property**

| **From the microeconomic viewpoint** | | including grey energy (in part, local heat) | |
|---|---|---|---|
| Scenario | Investment [€ millions] | Primary Energy Supply [TWh/yr] | A saving of 1 000 t $CO_2$/yr |
| **Low Price Scenario** | | | |
| Heat sold [TWh/yr] | 3.5 | | |
| Germany as a whole | 528 | 0.81 | 246 |
| **High Price / High Price Scenario with gas pipeline cost benefit** | | | |
| Heat sold [TWh/yr] | 1.15 | | |
| Germany as a whole | 173 | 0.26 | 81 |

Factors: Investment: €150 000/$TWh_{th}$; primary energy savings: 0.23 TWh/yr / $TWh_{th}$/yr; $CO_2$ reduction: 70 t $CO_2$/yr / $TWh_{th}$/yr

By way of summary, it can be determined that the cogeneration potential in this segment is very much dependent on further developments in natural gas prices. A high price level has a dampening effect while a moderate development as per Energy Report IV is beneficial instead. In itself, the implementation of potential is less dependent on the redevelopment cycles because the concepts accompanying this can be realised at any time. It shall be assumed, however, that corresponding ideas for concepts will often only come about if building renewal measures are on the agenda. By way of simplification, continual implementation over a 15-year period can be assumed.

## 2.3 The potential for cogeneration in non-residential buildings in the tertiary sector

### 2.3.1 Useful areas and the demand for heating in non-residential buildings

Tables 2-11 and 2-12 show the useful areas and the demand for heat for heating spaces and hot water for the years 2002 and 2020. Despite areas of increasing size, the demand for heat overall only drops slightly as a result of redevelopments in terms of heating and replacing old buildings with new ones.

**Table 2-11: The demand for heat for heating spaces and hot water in non-residential buildings in 2002 (excluding buildings used in agriculture)**

| | Number<br><br>000s | of which heated<br><br>000s | Total useful area<br><br>thousands of $m^2$ | of which heated<br><br>thousands of $m^2$ | Useful heat demand<br><br>$MWh_{th}$/Geb./yr | Final energy demand, total<br><br>$PJ_{Hu}$/yr |
|---|---|---|---|---|---|---|
| Small non-residential buildings | 2 674 | 2 072 | 735 | 603 | 48 | 459 |
| Medium-sized non-residential buildings | 320 | 248 | 315 | 233 | 138 | 159 |
| Large non-residential buildings | 247 | 192 | 897 | 580 | 432 | 384 |
| New builds after 2000 | 82 | 61 | 95 | 69 | 123 | 34 |
| **Total** | **3 323** | **2 573** | **2 043** | **1 485** | | **1 036** |

Table 2-12: **The demand for heat for heating spaces and hot water in non-residential buildings in 2020 (excluding buildings used in agriculture)**

| | Number<br><br>000s | of which heated<br><br>000s | Total useful area<br><br>thousands of $m^2$ | of which heated<br><br>thousands of | Useful heat demand<br><br>$MWh_{th}$/Geb./yr | Final energy demand, total<br><br>$PJ_{Hu}$/yr |
|---|---|---|---|---|---|---|
| Small non-residential buildings | 2 157 | 1 671 | 593 | 486 | 46 | 322 |
| Medium-sized non-residential buildings | 258 | 200 | 254 | 188 | 133 | 112 |
| Large non-residential buildings | 199 | 155 | 723 | 467 | 415 | 270 |
| New builds after 2000 | 611 | 458 | 708 | 517 | 120 | 228 |
| **Total** | **3 225** | **2 484** | **2 279** | **1.659** | | **932** |

### 2.3.2 Separation of that part of the non-residential building which is used by the industrial sector

The industrial potential of cogeneration is dealt with separately. For this reason, the non-residential buildings used by the industrial sector must be separated here. As a result, the residual heat demand and the useful areas are reduced accordingly. Data pertaining to the industrial heat demand for space heating and hot water were taken from the energy audit. The heated areas assigned to industry were determined on the basis of the numbers of employees, on the supposition that in the tertiary sector and in industry, roughly the same heated area is made available per employee (see Table 2-13 [German electricity association, 2003], [Energy Report IV, 2005]). As a result, a lower specific space heating requirement [kWh/$m^2$/yr] ensues in the tertiary sector than in industry. This is also corroborated by samples from specific properties.

Table 2-13: **Breakdown of the final energy demand and employed individuals between the tertiary sector and industry (2002)**

| **Final energy demand** | **[PJ]** |
|---|---|
| Industry, space heating | 217 |
| Industry, hot water | 21 |
| Tertiary sector, space heating | 692 |
| Tertiary sector, hot water | 147 |
| Transport, space heating | 112 |
| Transport, hot water | 0 |
| **Total** | **1 087** |
| Proportion, tertiary sector (incl. transport) | 78.2% |
| **Gainfully employed** | |
| In total | 38 671 |
| - of which in the tertiary sector | 32 184 |
| Proportion, tertiary sector | 83.2% |

Following deduction of the demand for heat on the part of industry, the final energy demand for space heating and hot water in the remaining non-residential buildings is still 809 PJ/yr.

### 2.3.3 Process heat consideration

In 2002, the consumption of final energy for process heat in the tertiary sector stood at 7.8 million tonnes of hard coal equivalent or 229 PJ (= 27% of the total demand for heat within the tertiary sector). Parts of this demand accrue in non-residential buildings and could be covered by cogeneration. According to estimates, approximately 30% of this demand for process heat can be assigned to the demand for hot water (e.g. laundry) or to the demand for space heating (e.g. horticulture). 20% of the remaining demand for process heat which cannot be covered by heat extraction from block-type thermal power stations falls to electricity and a further 20% to applications where temperature levels are high (e.g. bakeries).

### 2.3.4 Economic potential

All in all, the useful heat demand in non-residential buildings which is to be tested for cogeneration efficiency is in the region of 750 PJ/yr or 209 TWh/yr.
Table 2-14 shows the extent to which this demand for heat can be covered by cogeneration plants and how much this will cost. 62% (130 TWh) of this demand for heat can be covered by block-type thermal power stations with plant capacities of between approximately 2.5 kW and 1 700 kW, with electricity production costs of between 7.1 and 15.6 cents/kWh$_{el}$. This theoretical and structural potential is clearly greater than the economic potential which depends on the approaches to the price which is set for electricity. The costs specified relate to the High Price Scenario (50% surcharge on top of the energy prices set in Energy Report IV plus €10/t $CO_2$).

**Table 2-14: Structural potential for block-type thermal power stations in non-residential buildings (excluding industry) in 2002**

| | Capacity, block-type thermal power station kW$_{el}$ | Total investment € 000s / plant | Electricity production costs €/kWh$_{el}$ | Heat potential TWh$_{th}$/yr | Electricity potential TWh$_{el}$/yr |
|---|---|---|---|---|---|
| Small non-residential building, standard | 3.0 | 9.9 | 0.162 | 20.9 | 7.5 |
| Small non-residential building, favourable | 2.5 | 8.5 | 0.157 | 0.4 | 0.1 |
| Medium-sized non-residential building, standard | 11.3 | 23.7 | 0.143 | 8.3 | 3.8 |
| Medium-sized non-residential building, favourable | 9.4 | 19.8 | 0.135 | 0.2 | 0.1 |
| Large non-residential building, standard | 41 | 61.9 | 0.099 | 22.5 | 12.0 |
| Large non-residential building, favourable | 34 | 55.0 | 0.105 | 0.4 | 0.2 |
| New builds after 2000 | 10.6 | 22.2 | 0.143 | 2.8 | 1.3 |
| Small heating system | 69 | 95.0 | 0.092 | 16.6 | 9.3 |
| Medium-sized heating system | 166 | 216 | 0.082 | 21.4 | 13.2 |

| | | | | | |
|---|---|---|---|---|---|
| Large heating system | 414 | 497 | 0.076 | 13.3 | 9.0 |
| Very large heating system | 1 680 | 1 596 | 0.069 | 23.1 | 19.2 |
| **Total** | | | | **130.0** | **75.8** |

Process heat is already taken into consideration in the above table.

The specific heat demand will fall by 2020 on account of improvements in thermal insulation. However, this will be more or less offset by the strong growth in heated areas of 12%. The overall potential for electricity produced from cogeneration will increase slightly since it is assumed that the level of electrical efficiency of block-type thermal power stations will improve by one percentage point (cf. Table 2-15).
The cost effectiveness of the potential shown largely depends on the remuneration for electricity which can be set in relation to block-type thermal power stations.

Many of the non-residential buildings listed in Table 2-14 are to be found in areas which can be developed by district heating. In district heating areas, cogeneration can be portrayed more economically than in individual buildings or small heating systems which are powered by block-type thermal power stations. Taking into account this restriction on potential, the economic block-type thermal power station potential of medium-sized to very large heating systems when considered from the point of view of the national economy, which is presented in Table 2-14, is reduced to 18.5 $TWh_{th}$ and 13 $TWh_{el}$ respectively.

When considered from the microeconomic point of view, the costs of obtaining the electricity, which have been avoided, can be applied. The electricity prices which businesses have to pay to power companies are clearly higher than the total of the production costs and the network costs which have been avoided.

When considered from the microeconomic viewpoint, therefore, the economic potential is considerably higher. Table 2-15 shows the projection of structural potential by the year 2020.

**Table 2-15: Structural potential for cogeneration in non-residential buildings (excluding industry) in 2020**

| | Capacity, block-type thermal power station $kW_{el}$ | Total investment € 000s / plant | Electricity production costs €/$kWh_{el}$ | Heat potential $TWh_{th}$/yr | Electricity potential $TWh_{el}$/yr |
|---|---|---|---|---|---|
| Small non-residential building, standard | 3.1 | 10.1 | 0.162 | 16.3 | 6.1 |
| Small non-residential building, favourable | 2.5 | 8.7 | 0.157 | 0.3 | 0.1 |
| Medium-sized non-residential building, standard | 11.5 | 24.2 | 0.143 | 6.5 | 3.1 |
| Medium-sized non-residential building, favourable | 9.6 | 20.2 | 0.135 | 0.1 | 0.1 |
| Large non-residential building, standard | 42 | 62.9 | 0.099 | 17.6 | 9.9 |

| | | | | | |
|---|---|---|---|---|---|
| Large non-residential building, favourable | 35 | 55.9 | 0.105 | 0.3 | 0.2 |
| New builds after 2000 | 10.9 | 23.0 | 0.143 | 20.4 | 9.9 |
| Small heating system | 73 | 101 | 0.092 | 16.8 | 9.9 |
| Medium-sized heating system | 176 | 229 | 0.082 | 21.6 | 14.0 |
| Large heating system | 439 | 526 | 0.076 | 13.5 | 9.6 |
| Very large heating system | 1 780 | 1 691 | 0.068 | 23.4 | 20.3 |
| **Total** | | | | **136.8** | **83.2** |

When considered from the point of view of the national economy, cost effectiveness is only achieved in relation to the larger plants with capacities in excess of 100 $kW_{el}$. When considered from the microeconomic viewpoint, plants with capacities upwards of 50 $kW_{el}$ (small heating system) are also economical. According to the microeconomic calculation, the economic potential of block-type thermal power stations in non-residential buildings is increasing as a result to 22.7 $TWh_{th}$ or 15.9 $TWh_{el}$.

Table 2-16 again summarises the economic potential of cogeneration in non-residential buildings and segregates grid-bound supplies.

**Table 2-16: Economic potential of cogeneration in non-residential buildings under the High Price Scenario**

| High Price Scenario | Heat [$TWh_{th}$] | Electricity [$TWh_{el}$] |
|---|---|---|
| **Macroeconomic potential** | | |
| all non-residential buildings | 58 | 41 |
| of which, in areas which cannot be opened up by district heating | 18 | 13 |
| **Microeconomic potential** | | |
| all non-residential buildings | 74 | 51 |
| of which, in areas which cannot be opened up by district heating | 23 | 16 |

By 2020, there will be a slight improvement in electrical efficiency and, consequently, the cost-effectiveness of the block-type thermal power stations. The consequences in terms of economic potential remain negligibly small, however.

### 2.3.5 Investment sums, primary energy and $CO_2$ savings

Table 2-17 shows the investment made in cogeneration plants related to the structural potential regarding the various properties and heating systems, as well as the associated savings in terms of primary energy and $CO_2$. The grey energy is considered in relation to both primary energy and $CO_2$ savings. The corresponding figures for economic potential in the High Price Scenario are summarised in Table 2-18.

**Table 2-17: Investment, primary energy and $CO_2$ savings regarding cogeneration in non-residential buildings: structural potential**

| | Total | | | of which, in areas which cannot be opened up by district heating | | |
|---|---|---|---|---|---|---|
| | Investment | Primary energy savings | $CO_2$ savings | Investment | Primary energy savings | $CO_2$ savings |
| | € millions | $TWh_{HU}$ | Millions of tonnes of $CO_2$ | € millions | $TWh_{HU}$ | Millions of tonnes of $CO_2$ |
| Small non-residential building, standard | 7 007 | 7.8 | 2.0 | 2 208 | 2.4 | 0.6 |
| Small non-residential building, favourable | 820 | 0.1 | 0.0 | 258 | 0.0 | 0.0 |
| Medium-sized non-residential building, standard | 2 138 | 2.7 | 0.8 | 674 | 0.9 | 0.2 |
| Medium-sized non-residential building, favourable | 243 | 0.1 | 0.0 | 77 | 0.0 | 0.0 |
| Large non-residential building, standard | 4 562 | 9.2 | 2.6 | 1 437 | 2.9 | 0.8 |
| Large non-residential building, favourable | 553 | 0.2 | 0.0 | 174 | 0.1 | 0.0 |
| New builds after 2000 | 597 | 0.9 | 0.3 | 188 | 0.3 | 0.1 |
| Small heating system | 2 150 | 7.1 | 2.0 | 677 | 2.2 | 0.6 |
| Medium-sized heating system | 2 864 | 10.1 | 2.9 | 902 | 3.2 | 0.9 |
| Large heating system | 1 809 | 6.9 | 2.0 | 570 | 2.2 | 0.6 |
| Very large heating system | 3 039 | 13.0 | 3.9 | 958 | 4.1 | 1.2 |
| **Total** | **25 782** | **58.2** | **16.6** | **8 124** | **18.3** | **5.2** |

**Table 2-18: Economic potential of cogeneration in non-residential buildings under the High Price Scenario**

| **High Price Scenario** | Unit | All non - residential buildings | of which, in areas which cannot be opened up by district heating |
|---|---|---|---|
| **Macroeconomic potential** | | | |
| Primary energy savings | $TWh_{Hu}$ | 30 | 9 |
| $CO_2$ savings | Millions of tonnes of $CO_2$ | 9 | 3 |
| Investment sum | € billions | 8 | 2 |
| **Microeconomic potential** | | | |
| Primary energy savings | $TWh_{Hu}$ | 37 | 12 |
| $CO_2$ savings | Millions of tonnes of $CO_2$ | 11 | 3 |
| Investment sum | € billions | 10 | 3 |

## 2.4 Industrial cogeneration

In 2003, the demand for low- and medium-temperature heat within industry (hot water, space heating and process heat below 500 °C) stood at approximately 570 PJ/yr. A large part of this demand for heat can be covered by cogeneration. Cogeneration plants are generally not suitable for providing process heat at a higher temperate level.

Already today, the potential afforded by industrial cogeneration, above all, in those sectors of industry where the demand for heat is high, as is the case with the chemical industry, metal production and processing, papermaking, or the food and drink industry, is being utilised intensively. In 2003, 21.9 TWh of electricity was produced using an installed cogeneration capacity in the processing industry of 6.5 $GW_{el}$.

**Table 2-19: Installed cogeneration bottleneck capacity in industry (excluding mining and quarrying for stone and earth) in 2003 (German Association of Industrial Energy Users and Self-Generators, 2005)**

| Steam turbines [1)] (counter pressure turbines and machines for removing condensation) | Gas turbines | Internal combustion engines, gas and diesel engines | **Total** |
|---|---|---|---|
| 4.8 $GW_{el}$ | 1.5 $GW_{el}$ | 0.18 $GW_{el}$ | **6.5 $GW_{el}$** |

[1)] The proportion of condensation machines in steam turbines is estimated in accordance with the proportion in 2001 [German Association of Industrial Energy Users and Self-Generators, 2004]

### 2.4.1 Economic cogeneration potential which can be realised in industry

In comparison with residential buildings, industry is characterised by very heterogeneous energy demand structures with specific requirements in the various branches of industry and in individual enterprises. Since sufficient data is not available at enterprise level, the economic cogeneration potential which can be realised in industry was determined here on the basis of specific sectoral values.

The results show that large combined heat and power stations can generally be operated economically under the given framework conditions, but that their use is primarily restricted by the level of demand for heat within an enterprise.

The use of block-type thermal power stations with a capacity of less than 10 $MW_{el}$ is, however, not limited to the same extent by the quantity of heat demanded in an enterprise but primarily by the full duration of use which can be achieved. The analysis has shown that $CO_2$ surcharges in the order of €20/t $CO_2$ has a clearly positive impact on the framework conditions regarding the economic use of block-type thermal power stations.

Table 2-20 shows that, depending on the framework conditions, cogeneration plants may be operated economically using an installed cogeneration capacity of between 25 and 35 $GW_{el}$. The production of electricity from cogeneration which can be realised in this way is between 90 and 120 $TWh_{el}$/yr depending on the pricing option.

**Table 2-20: Industrial cogeneration capacity potential (microeconomic approach)**

| | Low Price Scenario | | High Price Scenario | | High price + Gas pipeline cost benefit | |
|---|---|---|---|---|---|---|
| **All figures in $GW_{el}$** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** |
| Medium-sized and large combined heating and power stations (> 50 $MW_{el}$) | 8.9 | 8.9 | 8.9 | 8.9 | 8.9 | 8.9 |
| Small combined heating and power stations (10-50 $MW_{el}$) | 11.0 | 11.1 | 11.0 | 11.1 | 11.1 | 11.5 |
| Block-type thermal power stations (1-10 $MW_{el}$) | 5.4 | 10.1 | 6.9 | 10.2 | 10.2 | 11.7 |
| Block-type thermal power stations (< 1 $MW_{el}$) | 0.0 | 4.9 | 0.0 | 0.0 | 3.6 | 4.8 |
| **Total** | **25.2** | **35.0** | **26.8** | **30.3** | **33.9** | **36.9** |

By 2020, the demand for low- and medium-temperature heat within industry will fall by approximately 20%. By raising the efficiency levels and the power-to-heat ratios of new cogeneration technologies, however, the potential for producing electricity from cogeneration can be kept largely constant.

The demand for low- and medium-temperature heat within industry amounting to 573 PJ/yr shall be regarded as an upper limit for the industrial cogeneration potential which can be utilised technically.

The efficiency of a cogeneration plant largely depends on the service life or the number of hours when the plant can be operated at full capacity which, in turn, are determined by the design of the plant and the load profiles of the energy demanded by the specific supply task.
Generally speaking, the full-load hours of the demand for process heat by an industrial enterprise are less than the full-load hours of the demand for electricity.

**Table 2-21: Total economic cogeneration potential which can be realised in industry under different framework conditions (microeconomic approach)**

| Size class | Low price €10/t $CO_2$ | | Low price €20/t $CO_2$ | | High price €10/t $CO_2$ | | High price €20/t $CO_2$ | | High price + Gas pipeline cost benefit €10/t $CO_2$ | | High price + Gas pipeline cost benefit €20/t $CO_2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) |
| Medium-sized and large combined heating and power stations (> 50 $MW_{el}$) | 25 | 30 | 25 | 30 | 25 | 30 | 25 | 30 | 25 | 30 | 25 | 30 |
| Small combined heating and power stations (10-50 $MW_{el}$) | 35 | 37 | 36 | 38 | 35 | 37 | 36 | 38 | 36 | 38 | 37 | 39 |
| Block-type thermal power stations (1-10 $MW_{el}$) | 20 | 20 | 32 | 31 | 24 | 23 | 32 | 31 | 32 | 31 | 36 | 35 |
| Block-type thermal power stations (< 1 $MW_{el}$) | - | - | **22** | 17 | - | - | - | - | 17 | 14 | 23 | 18 |
| **Total** | **81** | **87** | **114** | **115** | **85** | **90** | **93** | **98** | **110** | **112** | **122** | **122** |

Even in the case of cogeneration plants in the 10 to 50 $MW_{el}$ class, above all, the quantity of heat demanded is the limiting variable. In comparison, different pricing options only have a negligible influence on the potential of these plants of just under 40 $TWh_{el}$/yr.

In the case of block-type thermal power stations with a capacity of less than 10 $MW_{el}$, the impact of the different pricing options on the potential which can be realised economically is substantially greater. In this class, the potential for using cogeneration is less as a result of the quantity of heat demanded within an enterprise but limited rather by the full duration of use which can be achieved. On account of the high electricity credit associated with the “High price + Gas pipeline cost benefit” scenario, the potential of small block-type thermal power stations can be realised particularly well in this scenario.

The costs of $CO_2$ emissions have a significant influence on the minimum full-load hours. The potential which can be realised by block-type thermal power stations can increase appreciably with rising $CO_2$ certificate prices. With tightened $CO_2$ reduction targets, certificate prices of far in excess of €20/t $CO_2$ are anticipated.

The report shows that the differences between the micro and macroeconomic approaches are rather minor, meaning that in this instance, as regards the uncertainties which exist in the area of industrial cogeneration, this differentiation can be dispensed with in the scenarios under consideration, with only the results relating to the microeconomic variants shown.

### 2.4.2 Forward projection of the cogeneration potential in industry up to 2020

The future potential of industrial cogeneration utilisation is determined by the development in the demand for heat in the temperature range which is suitable for the application of cogeneration. The forecast trend in fuel consumption forms the basis for this assessment.

In contrast to the consumption of electricity, decreasing heat consumption is anticipated in almost all branches of industry despite increased production. All in all, by 2020, the demand for low- and medium-temperature heat will drop by around 20% to 1 314 PJ/yr.

This anticipated drop in the demand for heat will generally limit the possibilities for cogeneration use. On the other hand, the rising demand for electricity goes hand in hand with increasing power-to-heat ratios of future cogeneration technologies.

**Table 2-22: Development in the total economic cogeneration potential which can be realised in industry by 2020 (High pricing option, microeconomic approach, €20/t $CO_2$)**

| Class | 2003 | | 2005 [a)] | | 2010 | | 2020 | |
|---|---|---|---|---|---|---|---|---|
| | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) | Heat (TWh) | Elect. (TWh) |
| Medium-sized and large combined heating and power stations (> 50 $MW_{el}$) | 25 | 30 | 24.4 | 29.1 | 23 | 27 | 21 | 25 |
| Small combined heating and power stations (10-50 $MW_{el}$) | 36 | 38 | 35.7 | 37.7 | 35 | 37 | 33 | 35 |
| Block-type thermal power stations (1-10 $MW_{el}$) | 32 | 31 | 31.7 | 30.4 | 31 | 29 | 34 | 33 |
| Block-type thermal power stations (< 1 $MW_{el}$) | - | - | 5.7 | 4.6 | 20 | 16 | 20 | 17 |
| **Total** | **93** | **98** | **98** | **102** | **109** | **109** | **108** | **109** |

[a] interpolated between 2003 and 2010

In the other scenarios, in principle, the trend in the period under consideration up to 2020 will be the same, meaning that a presentation of all the individual results can be dispensed with at this point.

### 2.4.3 Volume of investment required to develop the potential for cogeneration in industry

Depending on the framework conditions, €14 to 24 billion will be required by way of investment to develop the potential for cogeneration in industry, allowing for the specific costs of investment in the various plant size classes, and taking into account the capacities for cogeneration which already exist today.

**Table 2-23: Volume of investment needed to develop the potential for expanding cogeneration in industry (microeconomic approach)**

| | Low Price Scenario | | High Price Scenario | | High price + Gas pipeline cost benefit | |
|---|---|---|---|---|---|---|
| **All figures in € billions** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** |
| Medium-sized and large combined heating and power stations (> 50 $MW_{el}$) | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| Small combined heating and power stations (10-50 $MW_{el}$) | 7.8 | 7.9 | 7.8 | 7.9 | 7.9 | 8.2 |
| Block-type thermal power stations (1-10 $MW_{el}$) | 4.2 | 7.9 | 5.4 | 8.1 | 8.1 | 9.3 |
| Block-type thermal power stations (< 1 $MW_{el}$) | 0.0 | 4.9 | 0.0 | 0.0 | 3.6 | 4.8 |
| **Total** | **14.1** | **22.9** | **15.3** | **18.1** | **21.7** | **24.4** |

### 2.4.4 Primary energy and $CO_2$ savings as a result of realising the potential for cogeneration in industry

As regards the potential for developing cogeneration in industry which has been illustrated, the avoided $CO_2$ emissions and the avoided primary energy use are determined below each time in comparison with the separate production of electricity and heat. It is assumed that a reference electricity mix is superseded by operation of the cogeneration plants. 80% of this is produced in natural gas combined cycle power stations (efficiency level 55.6%) and 20% in hard coal power stations (efficiency level 47.1%) and is burdened with specific $CO_2$ emissions of 463 g/kWh. As regards separate heat production, the heat is produced in a gas-fired boiler with an annual efficiency coefficient of 90%.

Depending on the price scenario, as a result of developing the potential for cogeneration in industry, the primary energy consumed in producing electricity and heat can be reduced by around 200 - 300 PJ/yr.

**Table 2-24: Avoided primary energy consumption by developing the potential for cogeneration in industry (microeconomic approach)**

| | Low Price Scenario | | High Price Scenario | | High price + Gas pipeline cost benefit | |
|---|---|---|---|---|---|---|
| **All figures in PJ/yr** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** |
| Medium-sized and large combined heating and power stations (> 50 $MW_{el}$) | 75.6 | 75.6 | 75.6 | 75.6 | 75.6 | 75.6 |
| Small combined heating and power stations (10-50 $MW_{el}$) | 89.1 | 90.5 | 89.1 | 90.5 | 90.5 | 93.2 |
| Block-type thermal power stations (1-10 $MW_{el}$) | 43.0 | 67.1 | 50.6 | 67.1 | 67.1 | 76.9 |
| Block-type thermal power stations (< 1 $MW_{el}$) | 0.0 | 39.2 | 0.0 | 0.0 | 31.4 | **41.7** |
| **Total** | **207.7** | **272.3** | **215.3** | **233.2** | **264.6** | **287.4** |

Consequently, $CO_2$ emissions totalling 19 to 27 billion tonnes per annum can be avoided. The $CO_2$ avoidance potential is greatest in those price scenarios with the highest cogeneration potential. As has already been illustrated, rising $CO_2$ costs increase the economic cogeneration potential which can be realised and, hence, also the possibilities of $CO_2$ reduction as a result of using cogeneration in industry.

**Table 2-25: Avoided $CO_2$ emissions by developing the potential for cogeneration in industry (microeconomic approach)**

| | Low Price Scenario | | High Price Scenario | | High price + Gas pipeline cost benefit | |
|---|---|---|---|---|---|---|
| **All figures in millions of tonnes per annum** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** | **€10/t $CO_2$** | **€20/t $CO_2$** |
| Medium-sized and large combined heating and power stations (> 50 $MW_{el}$) | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 |
| Small combined heating and power stations (10-50 $MW_{el}$) | 8.2 | 8.3 | 8.2 | 8.3 | 8.3 | 8.6 |
| Block-type thermal power stations (1-10 $MW_{el}$) | 4.1 | 6.4 | 4.9 | 6.4 | 6.4 | 7.4 |
| Block-type thermal power stations (< 1 $MW_{el}$) | 0.0 | 3.7 | 0.0 | 0.0 | 3.0 | 3.9 |
| Total | **19.2** | **25.3** | **19.9** | **21.6** | **24.6** | **26.8** |

## 2.5 Cogeneration potential arising from the utilisation of the energy content of biomass

The technical potential of cogeneration from biomass is limited by the availability of biofuels. Two scenarios are assumed when calculating the biomass available for cogeneration plants. In the first scenario, in which the previous trends are updated, a potential for biogenic remnants of 891 $PJ_{HU}$ plus 3.4 million hectares of arable land can be provided. In the second scenario, in which greater consideration is given to conservation interests than is normally the case today, this potential drops to 696 $PJ_{HU}$ plus 1.1 million hectares of arable land.

This biomass potential is not available in its entirety for use in cogeneration plants. Deductions must be taken into account for purely thermal use (e.g. in open fireplaces or pellet boilers) as well as for the production of biofuels. Allowing for these restrictions, the biomass potential is still sufficient to provide quantities of heat and electricity produced in a cogeneration works of up to 82 $TWh_{th}$/yr and 37 $TWh_{el}$/yr respectively.

If greater consideration is given to conservation interests, these figures drop to 53 $TWh_{th}$/yr and 23 $TWh_{el}$/yr. This potential can replace contributions to cogeneration from fossil fuels which are described in another part of this report.

**Table 2-26: Structural cogeneration potential arising from the utilisation of the energy content of biomass**

| | Allocated biomass potential TWh/yr | the proportion of which is used for cogeneration | Number of cogeneration plants | Heat from cogeneration $TWh_{th}$/yr | Electricity from cogeneration |
|---|---|---|---|---|---|
| Wood-fired combined heating and power station | 40 | 1.00 | 226 | 27 | 6 |
| Wood-gasifying block-type thermal power station | 15 | 1.00 | 4 903 | 8 | 5 |
| Stirling boiler | 15 | 1.00 | 73 933 | 9 | 3 |
| Straw-fired combined heating and power station | 12 | 1.00 | 68 | 8 | 2 |
| Co-incineration | 25 | 0.80 | 211 | 9 | 7 |
| Biogas, small, liquid manure | 15 | 0.15 | 21 111 | 1 | 1 |
| Biogas, large, renewable raw materials (with local heating) | 61 | 0.60 | 8 470 | 16 | 12 |
| Biogas, large, renewable raw materials | 61 | 0.00 | 8 470 | 0 | 0 |
| Waste incineration | 6 | 0.20 | | 1 | 0 |
| Power stations which utilise used wood | 22 | 0.20 | | 2 | 1 |
| **Total** | **272** | | | **82** | **37** |

As regards cogeneration based on biomass, a variety of largely innovative technologies are available but where we frequently have only limited experience of using them. Combined heat and power stations using wood chippings or straw, wood-gasifying block-type thermal power stations, Stirling engines and co-incineration in coal-fired power stations were investigated. There are also several types of biogas installations, partly in the form of small farmyard installations which just use liquid manure as raw material, and partly in the form of large installations which also recover crops cultivated specifically for energy purposes.

Table 2-27 shows how the use of biomass for producing heat and electricity could develop by 2020.

**Table 2-27: Development in the use of biomass from 2003 to 2020 (scenario: the expansion of renewable energies in an environmentally optimal manner)**

| **Type of biomass use** (including the biogenic share of the waste) | **2003** | **2010** | **2020** |
|---|---|---|---|
| | **[TWh]** | **[TWh]** | **[TWh]** |
| **Heat production** | 57 | 63 | 115 |
| Proportion relative to the final energy consumption for heat | 3.8% | 4.5% | 9.3% |
| **Electricity production** | 7.1 | no data | 23 |
| Proportion relative to the gross electricity consumption | 1.2% | | 4.6% |

A review of efficiency has concluded that from the point of view of the national economy, even today, none of the biomass cogeneration technologies listed can be operated in an economically viable manner. However, the technology involving wood-gasifying block-type thermal power stations is now very close to breaking even. However, each of these technologies can achieve a profit with the allowances under the Renewable Energies Act.

**Table 2-28: Investment, primary energy and $CO_2$ savings in relation to biomass cogeneration**

| | **Investment** <br> **€ millions** | **Primary energy saving** <br> **$TWh_{HU}$** | **$CO_2$ saving** <br> **Millions of tonnes of $CO_2$** |
|---|---|---|---|
| Wood-fired combined heating and power station | 4 348 | 39.2 | 8.2 |
| Wood-gasifying block-type thermal power station | 4 210 | 16.6 | 3.6 |
| Stirling boiler | 3 985 | 16.2 | 3.5 |
| Straw-fired combined heating and power station | 2 269 | 11.7 | 2.5 |
| Co-incineration | 546 | 22.8 | 5.0 |
| Biogas, small, liquid manure | 2 850 | 2.5 | 0.5 |
| Biogas, large, renewable raw materials (with local heating) | 9 397 | 40.1 | 8.8 |
| Biogas, large, renewable raw materials (without local heating) | 8 300 | 0.0 | 0.0 |
| **Total** | **27 605** | **149** | **32** |

## 2.6 The overall potential for cogeneration in Germany

Table 2-29 below summarises the economic cogeneration potential which can be realised in the areas under examination (microeconomic approach, High Price Scenario, surcharge of €10/t $CO_2$). As expected, the grid-bound supply of heat makes up the largest part of the potential, followed by industry. By way of contrast, the small cogeneration solutions which are linked to properties in residential buildings are negligible in terms of quantities. Given the comparatively low importance of cogeneration use in terms of covering the demand for useful cooling (both now and also in the future), its inclusion is dispensed with in the following general surveys.

**Table 2-29: Summary of the economic part potential (microeconomic approach, High Price Scenario, surcharge of €10/t $CO_2$)**

| **Part potential** | **Heat [TWh/yr]** | **Electricity [TWh/yr]** |
|---|---|---|
| Cogeneration from district heating[1)] | 219 | 245 |
| Micro-cogeneration in residential buildings in relation to properties | 1.2 | 0.4 |
| Cogeneration in non-residential buildings in the tertiary sector | 23 | 16 |
| Industrial cogeneration | 85 | 90 |
| Cogeneration from biomass | 0 | 0 |
| **Germany, total** | **328** | **351** |

[1)] Values apply to the total of supplies + the potential for development; the quantity of electricity for existing buildings is calculated in accordance with the power-to-heat ratios for development potential

Fig. 2-2 below shows the breakdown between the existing potential and the potential for development (microeconomic approach, High Price Scenario, surcharge of €10/t $CO_2$). As regards district heating, the existing potential shall not be equated with the actual state of supplies (and is therefore portrayed separately in the diagram), since the currently comparatively low power-to-heat ratio still yields a considerable potential for higher electricity production from cogeneration in this area. A similar situation applies to industry: while the heat potential has already largely been exploited, here too, the increase in the power-to-heat ratio still has much to offer in terms of raising the efficiency of electricity from cogeneration which is still low at present. All in all, roughly half of the calculated economic potential of heat from cogeneration is currently exploited, dropping to approximately one third in the case of the potential of electricity from cogeneration.

[Key to diagram:
Summe = total
Wirtschaftliches Potenzial = economic potential
Wärme, Bestand = heat, existing supplies
Wärme, Ausbau = heat, expansion
Strom FW = electricity from district heating
Strom, Bestand = electricity, existing supplies
Strom, Ausbau = electricity, expansion
KWK aus Biomasse = cogeneration from biomass
Objekt-Kleinst-KWK in WG = micro-cogeneration in residential buildings in relation to properties
KWK in NWG im Sektor GHD = cogeneration in non-residential buildings in the tertiary sector
Industrielle KWK = industrial cogeneration
Fernwärme-KWK = cogeneration from district heating]

Notes:
The actual quantity of electricity for district heating supplies in 2003 is based on a mean power-to-heat ratio of 0.478.
The potential quantity of electricity for district heating supplies is calculated in accordance with the power-to-heat ratio for the potential to expand.
The shares of existing supplies are estimated in relation to non-residential buildings in the tertiary sector.

**Fig. 2-2: Economic potential of cogeneration**

Comparing this potential with suitable comparison figures results in the following proportions:

- the heat potential totalling 328 TWh corresponds to roughly 32% of the useful heat consumption in Germany in 2004 of 1 026 TWh,
- the electricity potential amounting to 351 TWh corresponds to roughly 57% of the current gross electricity production in Germany of 611 TWh (including network losses and private consumption).

Here, these figures are only designed to clarify the scale of the potential established. It may not be concluded directly from this that these proportions can be achieved directly under the stated framework conditions. Expanding cogeneration on such a scale would naturally very quickly result in considerable interdependencies on the market, with a corresponding impact in terms of determining potential.

The overall primary energy savings resulting from this potential (including grey energy) and reductions in $CO_2$ emissions are listed in the table below together with the investment required for implementation (microeconomic approach, High Price Scenario, surcharge of €10/t $CO_2$).

As regards cogeneration from district heating, however, consideration has only been given to the potential for development (143 TWh/yr of heat sold). The reason for this is the lack of data relating to existing district heating installations which does not permit any meaningful statement on efficiency improvements or the costs of modernisation within the framework of this investigation.

Consideration shall therefore be given to the fact that the totals for Germany should not be directly related to the individual tables. The actual values would be even higher. Significant scales also result with this restriction, however, in the form of reductions in the use of primary energy resources and $CO_2$ emissions which can be achieved as a result of utilising the cogeneration potential.

**Table 2-30: The potential for savings and the costs of investment of the economic part potential (microeconomic approach, High Price Scenario, surcharge of €10/t $CO_2$)**

| Part potential | Primary energy saving [$TWh_{HU}$/yr] | $CO_2$ saving [millions of tonnes/yr] | Investment costs [€ billions] |
|---|---|---|---|
| Cogeneration from district heating[1)] | 101 | 31 | 40 |
| Micro-cogeneration in residential buildings in relation to properties | 0.3 | 0.1 | 0.2 |
| Cogeneration in non-residential buildings in the tertiary sector | 12 | 3 | 3 |
| Industrial cogeneration | 60 | 20 | 15[2)] |
| Cogeneration from biomass | 0 | 0 | 0 |
| **Germany, total** | **173** | **54** | **58** |

[1)] Values only apply to the potential for development; existing supplies are not taken into consideration.
[2)] This value only relates to the potential for development.

## 3. Analysis of the barriers to expanding cogeneration

This study highlights a significant difference between the potential which can be realised as a result of success at a microeconomic level and the actual cogeneration potential which has been realised hitherto.

Obviously, the yields which can be achieved by expanding cogeneration and district heating are regarded as being too low by many decision makers, both in industry and in the energy sector. The high expectations in terms of the payback period, the risk involved and the profit which can be achieved can be satisfied more easily by other forms of investment.
These high expectations in terms of yield appear to be the major obstacle to the expansion of cogeneration in Germany.

### 3.1 Barriers when supplying fuel

According to the statement contained in Energy Report IV, 2005, the use of energy resources in district heating, which is largely produced by cogeneration, will alter markedly by 2020. Brown coal and fuel oil are practically no longer used in the production of district heating, while hard coal is still only used in industrial cogeneration, as demonstrated by Table 3-1.

**Table 3-1: Development in the structure of energy resources in the district heating sector over the period 2000-2020**

| Energy resource | 2000 | 2010 | 2015 | 2020 |
|---|---|---|---|---|
| | Production quota as a % | | | |
| Hard coal | 27.0 | 6.4 | 5.3 | 4.5 |
| Brown coal | 8.9 | 0.2 | 0.1 | 0.1 |
| Light fuel oil | 3.8 | 4.4 | 2.2 | 0.8 |
| Heavy fuel oil | 0.2 | 0.1 | 0.0 | 0.0 |
| Natural gas | 49.2 | 52.9 | 53.7 | 53.3 |
| Other (biomass, rubbish, geothermics) | 10.9 | 36.0 | 38.7 | 41.3 |

Against this background, the availability and trend in the price of natural gas, biomass and rubbish (geothermics does not play a significant role in terms of quantity) could represent a possible barrier to the expansion of cogeneration, meaning that these aspects are to be analysed in greater detail below.

#### 3.1.1 Natural gas

Despite rising energy consumption worldwide, the authors of Energy Report IV, 2005, do not expect any bottlenecks in energy resources up to 2030. The dependence of energy supply on politically and economically unstable transporting and transit countries will continue to grow, however, along with the supply risks. In the overall consideration of all sectors where energy is consumed, oil will also become the most important energy resource by 2030. Natural gas will increase its market share at the expense of coal and, from 2010, will be ahead of coal. Coal will continue to be important, however, primarily in developing countries and emerging markets.

As far as Europe is concerned, on the one hand, a rising demand for natural gas and, on the other, a significant drop in its own support mechanisms, is anticipated. Consequently, the dependence on imports will rise, in which connection increased competition in terms of demand with other regions (USA, Asia) will also be anticipated if natural gas is also sold over larger distances on account of cost reductions in the transport sector (Liquefied Natural Gas Technology).

The German market for heating energy is of the opinion that the increasing use of natural gas in large power stations represents growing competition for these energy resources which produce low levels of emissions. All this will be reflected in actual rising natural gas prices.

The quantity of natural gas which is available for use in cogeneration plants does not appear to be limited, however, because the supply of natural gas for the heating market has expanded extensively and the gas may either be used directly or for producing heat with the additional production of electricity. While bottlenecks and interruptions to supply cannot be ruled out, nevertheless, they will not affect the cogeneration sector any more than any other users. As to whether this will impede the further expansion of cogeneration, however, will depend on the evaluations made by the enterprises at the time of investment.

Other factors which may influence developments in gas prices include the new energy management legislation with the introduction of network regulation and the trend towards concentration within the energy sector.

The high price volatility of natural gas has less of an impact on the production of electricity from cogeneration than on the uncoupled production of electricity from natural gas because the sale of heat produced from cogeneration is in competition with the heat produced from natural gas in individual heating installations, the price of which suffers from the same fluctuations. In this respect, the fluctuating prices of natural gas may even serve as an argument for expanding cogeneration technology.

### 3.1.2 Biomass

Since the utilisation of biomass is one of those renewable energies which can be tapped most economically, the potential which exists locally will already be largely exploited by 2020, provided the previous policy favouring climate protection is continued. Consequently, further price trends will largely depend on the possibilities of importing bio-energy resources.

In the short term, it is already uncertain as to what areas will be available for the cultivation of energy crops. Here, there is competition for space with conservation interests (extensive cultivation results in lower yields per hectare on the former arable land areas and, consequently, to an increased need for space) as well as with the utilisation of arable land for the production of biofuels.

Against this background, competition for scarce cultivation areas for biomass to be processed for energy recovery must be regarded as a serious obstacle for the adequate provision of biomass for use in cogeneration.

### 3.1.3 Waste

Municipal waste plays an important role as an energy resource in the production of district heating. In 2001, the category “Rubbish and other” accounted for 42.4 PJ, or approximately 8%, of fuel use in combined heat and power stations and heating stations [Federal Ministry of Economic Affairs and Technology, 2003]. As regards the quantity of waste incinerated in 2000 amounting to roughly 13 million tonnes, Dehoust et al. [2002] estimated an energy content in the region of 133 PJ, with a biogenic share of approximately 82 PJ.

A trebling of the heat produced from waste would also be possible in theory, in which connection the framework conditions have improved further as a result of the ban on the disposal of untreated waste from households and industry, which has been in place since June 2005, by means of the Order on the landfilling of waste [2001].

### 3.2 Political and legal framework of the energy industry

#### 3.2.1 Increased profitability requirements

The liberalisation of the energy sector, introduced in 1998, resulted in a situation whereby the microeconomic and financial targets of utility companies took priority over social objectives, such as security of supply or environmental protection and conservation.

Alongside this, expectations in terms of return on capital and the shortest possible investment payback period rose.

In the opinion of the power companies, such behaviour was entirely rational given the increased investment risks. Nevertheless, it represents a significant barrier to the expansion of cogeneration because increased and lengthy capital commitment must be anticipated, along with the additional risks associated with the heating market, when supplying district heating (production and distribution) compared with supplying electricity.

On the part of independent industrial power producers and smaller public utility companies which partly substitute electricity obtained from third parties with electricity produced by their own cogeneration plants, strong competition, and the falling prices associated with this, which was made possible shortly after liberalisation by the overcapacity in terms of production which existed at that time, frequently resulted in a situation where independent production in cogeneration plants became uneconomical and had to be discontinued, or the building of new cogeneration plants which was planned did not come to fruition.

The commercial attractiveness of building cogeneration plants, which has declined for the reasons mentioned above, consolidates the known obstacle of the "disparity in the electricity efficiency calculation" which was already described on page 200 in the 2000 study compiled by the German District Heating Association regarding pluralistic long-distance and local heat supplies: for (potential) cogeneration operators, the cost effectiveness of investment in cogeneration is measured using current reference conditions, i.e. by way of alternative, the low costs of producing electricity in an "historic" generation system (which is at an advanced stage of depreciation) are included in considerations and not the production costs of a new power station which is to be built as an alternative, as this would be prudent from the macroeconomic point of view (Disparity in the electricity efficiency calculation).

Since 2001, electricity prices have risen sharply on the wholesale market. Consequently, the "electricity efficiency disparity" has diminished, although the advantage of the mixed calculation involving large production concerns over the individual calculations of smaller cogeneration operators will always remain.

#### 3.2.2 Impact of emissions trading

The era of emissions trading in Germany and across the European Union began in January 2005. By passing the following two acts, the German *Bundestag* established the legal framework for transposing the EU Emissions Trading Directive of 13 October 2003:

- the Act on greenhouse gas emission allowance trading, and
- the Act on the national allocation plan for greenhouse gas emission rights during the allocation period 2005 to 2007 (the Allocation Act 2007)

The rules concerning emissions trading cover $CO_2$ emissions from all medium-sized and large installations in the areas of energy conversion, refinery processes, coking plants, and the steel, cement, glass, ceramics, wood pulp and paper industries. For those plants participating, starting from January 2005, $CO_2$ emissions are linked to tradeable emission allowances.

The following two aspects of emissions trading are important, above all, in the development of cogeneration:

- limiting emissions trading to installations with a furnace thermal capacity in excess of 20 MW and
- the exclusion of energy conversion plants in other sectors, apart from those mentioned above, i.e. in the housing industry or the tertiary sector, for instance.

Both regulations represent a barrier to the expansion of cogeneration technology.

The operators of “large" cogeneration plants are of the opinion that those individual firing installations and cogeneration plants which do not participate in emissions trading (up to and including 20 MW) have a clear competitive advantage because they do not have to buy any additional certificates when expanding production and because their administrative costs are low.

On the other hand, the operators of “small” installations do not have the opportunity either to reduce their $CO_2$ emissions by means of particularly efficient modes of operation or to sell surplus certificates which are issued free of charge on the market, thereby generating additional revenue.

The exclusion of heat produced in private heating installations, and in installations of other branches of industry, from emissions trading appears to have a more serious effect.

In expanding district or local heating, especially when using cogeneration, many $CO_2$ emissions from individual heating systems of this nature can be avoided. In central heat production plants, however, larger quantities of fuel must be used and additional certificates acquired on the market given the increase in central emissions.

### 3.2.3 Effects of the new Energy Management Act

Together with the new orders relating to network access and network usage costs concerning electricity and gas, the energy management law which entered into force in July 2005 represents an entirely new legal framework for the German energy industry whose effects on the prospects for developing cogeneration within the framework of this “hurdles analysis” cannot be examined in detail. The most important aspects need to be focussed on, which delivers the following assessments:

A key change to energy management law is the newly required legal and organisational unbundling of the network operation from trading and production activities in the frequently integrated power companies.

Without going into the details of the provisions governing unbundling and their partly fixed-term exemptions at this point, it can nevertheless be established that the impact of this so-called unbundling on the development of cogeneration within traditional energy management is not expected to be positive.

The sale of natural gas and district heating may continue to be controlled by the local power companies and managed by a single organisation unit. This also means that the resulting obstacles, including, for instance, giving consideration to the shortfall in profit contributions in the gas sector when customers change over to district heating, will continue to occur.
Generally speaking, however, the unbundling provisions have a positive impact on the conditions of the cogeneration plants operated by third parties because they increase transparency in relation to calculating the electricity and gas network charges.

In the case of network operators which cover several branches, including, also, district heating networks, the cost pressure arising from the incentive regulation could result in a permanent drop in the interest shown by network operators in the establishment and expansion of district heating networks, with a strategy of consolidating existing networks adopted instead. This would represent a serious and permanent obstacle to the aim of expanding cogeneration.

On the other hand, unbundling and regulation of the electricity network's operation will result in an improvement in the market prospects for independent cogeneration operators who wish to feed their surplus electricity into the network.

Compensation amounting to the avoided network costs is due to operators of decentralised production plants. The "actual avoidance work in kilowatt hours" and the "actual avoidance capacity in kilowatts" are mentioned as significant factors in determining the network charges which have been avoided. Compared to the provisions of the Agreement regarding access to and use of the power network [2002] which were in force up to June 2005, this represents a substantial improvement in the legal position of cogeneration plant operators and, consequently, must be considered as removing obstacles regarding the expansion of production by cogeneration.

### 3.2.4 Application-specific barriers

Chapters 2.2.4.1 "Barriers to cogeneration and decision patterns in industry and small-scale consumption" and 2.2.4.2 "Barriers and decision patterns in the district heating public utility companies" of the study compiled by the German District Heating Association entitled "Pluralistic heat supply" [2000] contain a detailed analysis of application-specific barriers.

Regarding the barriers described at that time, unless they have already been described in the preceding sections, the following Table 3-2 provides an assessment each time as to whether the individual barrier still exists today in this form, whether it has been removed (in part), or even whether it has been consolidated today.

**Table 3-2: Comparison of application-specific barriers in 2000 and 2005**

| Barriers in 2000 | Barriers in 2005 |
|---|---|
| **High economic risk** based on uncertainty regarding the development of the electricity market | Still present, consolidated further still by uncertainty regarding long-term energy policy. |
| **Reduction in the demand for heat** in the industrial sector in the low-temperature heating area | Will also continue in this way up to 2020. |
| **Inadequate obligation to accept and pay for electricity from cogeneration** | The situation has improved compared to 2000. As regards small cogeneration plants with an electrical capacity of up to 2 MW, the obligation now exists under Section 4 of the Cogeneration Act 2002 to remunerate the electricity supplied at the average price for base load electrical energy at the Leipzig-based European Energy Exchange which applied each time in the preceding quarter. In the case of electricity from larger plants, the "standard price" applies as agreed. Once the support under the Cogeneration Act ends in 2010, this barrier could be consolidated again. |

| | |
|---|---|
| **Unfavourable provisions concerning back-up electricity supplies** decrease the credit items of cogeneration producers from the avoided network charges | This barrier still exists, although the situation facing cogeneration operators has alleviated somewhat. |
| **Technical barriers in the case of gas turbine combined heat and power stations and counter pressure machines,** which have a fixed ratio of electricity to useful heat | These barriers remain. |
| **High fixed costs** associated with cogeneration plants and heating networks require the longest possible contractual commitments between customers | With the increasing globalisation of the economy, the willingness of the heating customers to conclude long-term agreements concerning the supply of heat has dropped further still, both because commercial customers and the public service sector are today even more dependent on being able to react to changes in their framework conditions in a flexible manner at all times. |
| Industrial cogeneration has to contend with particular obstacles: a lack of interest, a lack of in-house know-how, high transaction costs for information, overly high amortisation expectations and a lack of capital | The general trend towards concentrating on core business has, in the first instance, resulted in a consolidation of these obstacles. Committing capital, which is scarce, over the long term, is rather viewed as an encumbrance and not as support for the core business, and is therefore not practised. Accordingly, a trend towards concentrating and outsourcing energy and, specifically, heat supplies, can be identified, so that enterprises which specialise in this are deployed and, for example, build and operate cogeneration plants in the course of contracting. The promotion of contracting can be viewed as a good step for the purpose of improving the prospects for cogeneration in the industrial and tertiary sectors. |
| Cogeneration projects within industry and power companies which are located downstream are prevented as a result of the structure of the electricity supply agreements | Increased competition on the electricity market and the sharp rise in electricity prices over a number of years since the cut in production overcapacity have ensured that although this obstacle has not disappeared, it has lost some of its importance. |
| The successful expansion of gas supplies (using separate furnaces) | In recent years, too, the expansion in individual supplies of natural gas has continued more rapidly than the expansion in district heating because the individual supply of natural gas is not confronted with barriers occasioned by matters of power efficiency and because the distribution stage entails substantially lower investment on the part of the power companies. |

| | |
|---|---|
| Competition between gas and district heating within enterprises | ... still impedes the development of district heating supplies and the realisation of the economic cogeneration potential which is feasible in this area. This not only applies when opening up developing areas but also, in particular, when constructing a district heating supply in areas supplied with gas. Together with the higher demand for capital and the longer start-up losses, this may signify the end for many a district heating project. |
| A lack of flexibility associated with cogeneration from both the technological and microeconomic viewpoints | This impediment continues to exist and has rather gained in importance, given that the speed of development in the electricity and heating markets has increased. |

**The extreme dependency of district heating sales on the weather** [Ebeling, 2002] must be cited as a further application-specific barrier. In this regard, the partly unusual weather events over recent years have contributed to an increase in uncertainty and the commercial risk associated with expanding district heating supplies.

**The financial needs of the State, and the municipalities in particular,** impede the expansion of district heating and cogeneration because in many places, there is insufficient money to connect public property to district heating. Consequently, an important potential cannot be developed in terms of reducing start-up losses.

### 3.2.5 Barriers resulting from administrative and approval procedures

The construction and operation of cogeneration plants in Germany is subject to various administrative and approval procedures which are dependent on the size and type of the installation. The range of Acts and Orders to be observed extends from building regulations law, via the Federal Water Management Act and the Federal Pollution Control Act, to industrial safety law, in which connection this list is by no means complete. Responsibility for implementing these regulations and monitoring observance of the same generally rests with the local authorities or special institutions in the Federal *Länder*.

A detailed critique of the individual Orders and Acts relating to the construction and operation of cogeneration plants cannot be carried out at this point. The plethora of Orders and Acts to be observed in itself constitutes a barrier, although this does not just affect the expansion of cogeneration. Here, the execution of a sensible reduction in the requirements and bans without relinquishing important rights governing the protection of people and the environment represents a longer-term challenge for all levels of policy and administration cannot be specifically related to the theme of cogeneration.

### 3.2.6 Expiry of the Cogeneration Act

The Cogeneration Act 2002 supports the preservation and modernisation of cogeneration plants which have been operating continuously prior to the entry into force of the Act, and those plants which have undergone modernisation by the end of 2005 at the latest, or which have been newly built to replace an old plant, in the form of surcharges on electricity supply payments. In this regard, a distinction is drawn between old existing energy plants, new ones and modernised plants regarding the amount of surcharge which goes down from year to year and regarding the duration of these surcharge payments. The final surcharges are to be paid out by 2010, in which connection special provisions exist in relation to micro-cogeneration plants with an electrical capacity of up to 50 kW (where payments will end by 2018 at the latest) and fuel cell installations (where payments will end by 2020 at the latest). According to the Act, there are no surcharges for electricity produced by cogeneration plants with an electrical capacity in excess of 2 MW which were built after 1 April 2002.

As regards existing stocks of “large” cogeneration plants, funding or protection and support for modernisation was subjected to a time limit from the outset, so that operators and owners would be able to adjust. The ten-year bonus payments for electricity produced from micro-cogeneration plants which were envisaged, in the first instance, just for plants built up to 2005, were extended in the summer of 2005 for three years up to the end of 2008, meaning that the plant manufacturers have a longer subsidised market introduction phase.

A decisive factor in the further development of cogeneration will be whether the Act is amended and how.

### 3.3 Conclusion and measures for overcoming the barriers

The analysis highlights a significant difference between the existing economic potential of cogeneration and the potential which could be realised. In this connection, a calculated interest rate of 8% from the microeconomic viewpoint and, depending on the nature of the investment, differentiated service lives of between 20 (in the case of block-type thermal power stations, upwards of 12) and 40 years, were taken into account.

Obviously, the yields which can be achieved by expanding cogeneration and district heating are regarded as being too low by many decision makers, both in industry and in the energy sector. The high expectations in terms of the payback period, the risk involved and the profit which can be achieved, can be satisfied more easily by other forms of investment. This high expectations in terms of yield appear to be the major obstacle to the expansion of cogeneration in Germany.

In addition, a wide range of further barriers exist which ensure that cogeneration use in Germany is not developed further in accordance with its cost effectiveness and its positive contribution to conserving resources and environmental protection and conservation.

In view of the significant potential which has not been fully exploited hitherto, and with one eye on existing findings regarding execution of the Cogeneration Act and implementation of the self-commitment on the part of industry regarding $CO_2$ savings, the way in which the new building and modernisation of cogeneration plants can be accompanied by State measures shall be examined.

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