# Security of energy supplies and cost-cutting due to the own small power plant

## Changing portfolio property to decentralized energy supply

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## Contents



## Abstract

Today's sustainability standards and building codes usually lead to high-quality and energy-efficient buildings being newly constructed. Yet, they represent only a small portion of the real estate portfolio. For the large number of existing real estate, there still is considerable potential for the saving of primary energy and therefore the sustainable reduction of the operating costs for an increase in economic efficiency and environmental compatibility in the utilisation phase. This is possible through the use of combined heat and power generation plants in suitable real estate. Such a system can be implemented by the owner, or as energy services by means of outsourcing. Subsidiary programs provide additional economic advantages. This paper is based on recent developments in Germany covering mainly German property at the example of a CHP generation plant.

# 1 Introduction

Usual office buildings are technically able to be used for as long as 70 years. Yet, their attractiveness is determined mainly by the economic efficiency in the particular stage of the real estate's life cycle having the main impact on being fully let or being unoccupied, besides architecture and location.

The cost efficient and also energy-saving use of a property is the main goal for commercial real estate. Rising on a regular basis, energy prices of fossil fuels usually being imported and more and more strict guidelines to create energy-efficient buildings lead to extensively optimized structures in new real estate. There exist several ambitious climate policy objectives of the German government. The aim is to decrease greenhouse gas, especially $CO_2$ by 40% until 2020 (based on 1990), to increase the use of renewable energy with eco power by 35% and to construct more and more energy efficient. This might be easy to achieve with new real estate, yet existing property is more difficult to handle.

Having decided to quit nuclear power, German government made the final inition for extending the use of renewable energy without having appropriate storage facilities or a power grid suited to lead electricity from north to south. Not only rapidly rising cost for building power infrastructure and rising cost for energy in general are a challenge, security of energy supply might be critical. Therefore, real estate sector has to adopt and property owner have to rethink their strategy to save and utilise energy, too.

Potential measures to reduce energy consumption and lower emissions of buildings are the improvement of the building envelope in order to reduce the heating and cooling needs, as well as the less expensive, easily realizable and in comparison more preferred replacement of heating installation using state of the art. As a third component there is to mention an energy-conscious user behaviour, which although being supported by technical building systems, marginally can be enforced. Their combination would be optimal.

Once a commercial property is in the utilisation phase, subsequent investments first need proven profitability for the owner. If at the same time the owner is occupant, he might gain the perspective of the user as well. Though often being rental property, replacement investments only are feasible when there is a clear positive perspective in terms of rising returns. In most cases, objectives of environmental policies are difficult to achieve, especially lacking a legal obligation to modernize in every case and by reason of the right of continuance to keep the status quo. Therefore, the Federal Government is trying to offer a limited incentive with support measures.

# 2 Delay in modernization and maintenance of existing property

According to a study of 2008, an extrapolation of real estate assets in Germany concludes in approximately 9 bn. Euro. Replacement costs of the buildings are estimated at a total of about 6.6 billion Euro, consisting of 59% residential buildings and 41% commercial and infrastructure. [1] There is no appropriate data of the amount and the age of office space, however investigations exist for selected sites, i.e. usually cities in an urban centre. Studies of real estate portfolios reveal an age structure of 43% from the post-war period dating back to the 1950. Only about 34% of the current assets can be attributed to the recent period of construction in the 1990s. [2]

If being a profitable investment, also office space of old built is to be modernised and placed on the state of the art. However, this property suffers sometimes from an enormous delay in modernization and maintenance, in particular with regard to the building technology, i.e. the heating systems. Fig. 1 is a summary of 6 m. oil burning installations in Germany obligatory to recurrent inspection, which among environmentally-relevant defects showed a large quantity of legacy systems.

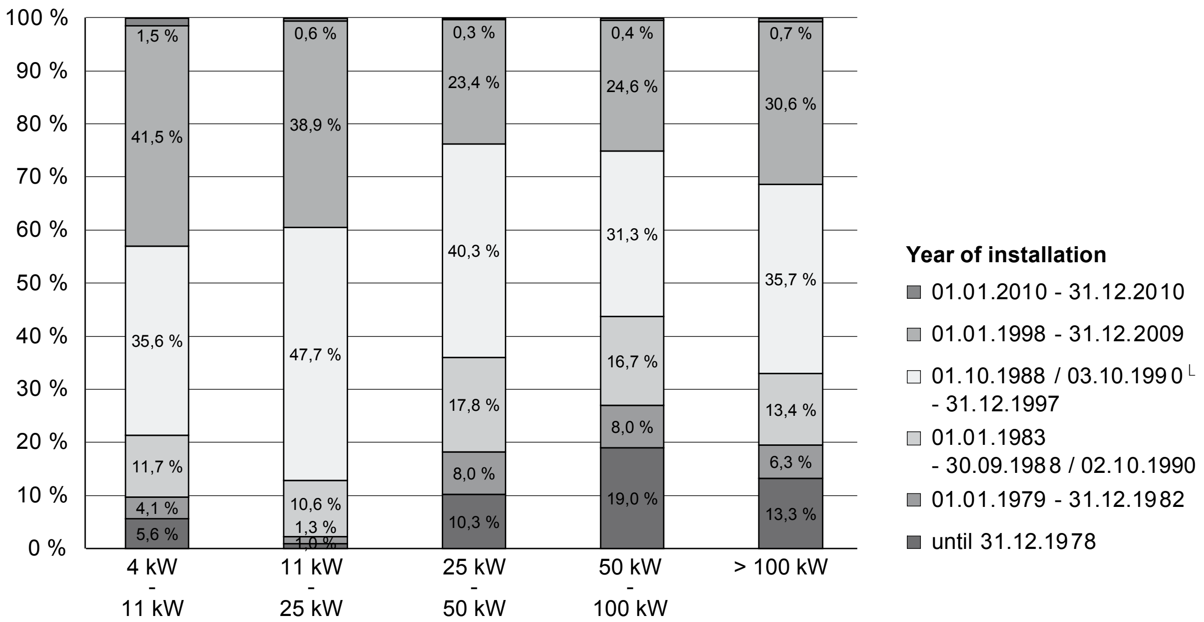


Figure 1: Oil burning installations in Germany obligatory to recurrent inspection, ordered by year of construction (2010) [3]

50% are represented by systems up to 25 kW due to installations in residential property. They are in relatively new condition. The medium class contains 41% and nearly 10% are installations with 50 kW and more. Especially systems of higher power are outdated. The situation of natural gas-fired plants concerning the age of the power classes can be compared to this, however 67% are smaller installations of up to 25 kW. [3] Large plants up to 250 MW are complex installations. Due to high costs for replacement investments there is more attention to servicing and operating concerning lower proportional personal expenditures.

In a ranking of utilization costs in building design and construction according to German standard DIN 18960 for operating costs, the most important positions can be identified to be first electricity and second heating and cooling. Both can be particularly influenced through use of a CHP plant. Other cost driving groups (cleaning and water supply) are of much lower potential. [4]

# 3 Increase of energy efficiency

## 3.1 Potentials of portfolio property

Energy efficiency aims to avoid system losses in the production, conversion, distribution and use of energy. It affects the entire value chain of energy, what comprehends energy recovery and in general all sectors using energy (electricity, heat, fuels). There is potential on the entire supply chain: energy production may take place in power plants of higher efficiency and transmission losses can be avoided by generating electricity locally. The amount of site energy can be reduced by combined transformation into several types of energy, e.g. by use of combined heat power (CHP) or trigeneration (CHP with cooling). Finally, energy services might be provided more efficiently. [5]

Most real estate require both electricity and heat. Concerning electricity, the consumer has to determine its electricity provider and may choose the type of generation by selecting a tariff consisting of renewable or more “old-fashioned” fossil fuels. Besides this, he is completely at the mercy of the company and the market when it comes to price increases. Only few real estate use district heating. They require to be situated within a radius of maximum 10 km to a power plant – otherwise energy losses are high and the increasing effort for heat distribution usually is not reasonable. [6]

Therefore, it is obvious to install an own, decentralized "small power station" to benefit from cogeneration (or trigeneration) saving primary energy as well as reducing emissions of $CO_2$ (Fig. 2). The overall efficiency of combined energy transformation in a CHP is much higher. Obtaining conventionally generated electricity may result in energy loss of more than 70% of primary energy. The exploitation of fuel energy can be improved significantly by CHP so that primary energy consumption can be reduced by one-third and emission of $CO_2$ up to 50%. [7, 8]

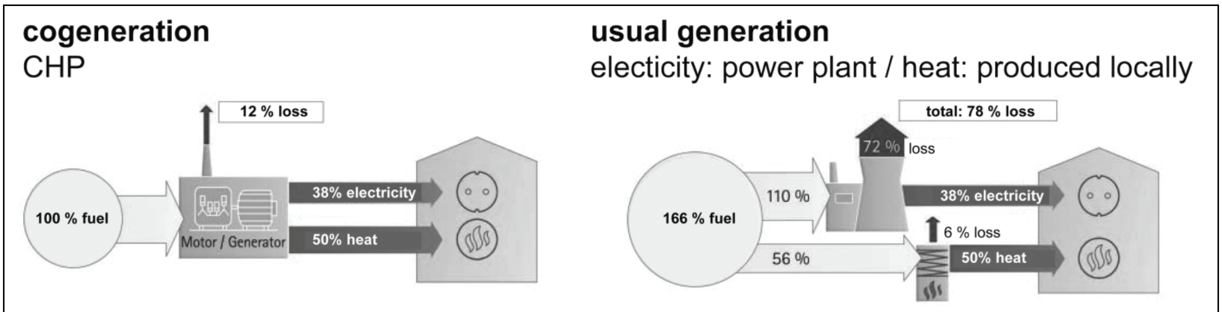


Figure 2: Comparison of CHP and usual generation of electricity and heat [7]

Cogeneration plants in general offer a high overall efficiency. The CHP coefficient is the ratio of electric power and used portion of lost heat – obtainable power output increases with its amount. Furthermore, the better the part load behaviour is, the better the utilisation of the cogeneration unit can be. Depending on the mode of operation, there is not always need of full load, sometimes resulting in significant decreases of the potential efficiency. Due to their size and power output, steam power plants, gas turbines and their combination only are suitable for large customers and are listed for the sake of completeness. CHP, however, can be built as a compact installation and easily placed in the boiler room, or as a container outside the property. The fuel cell is still in test stage and may soon convince with its advantages, i.e. hardly any exhaust and little maintenance because of few moving parts. (Tab. 1)

| | **usual cogeneration methods** | | | | | **recent cogeneration methods** | |
|---|---|---|---|---|---|---|---|
| | **steam power plant** | **gas tur-bine** | **gas and steam turbine** | **CHP** (gasoline) | **CHP** (diesel) | **Stirling engine** | **fuel cell** |
| **electric power [kW]** | 5.000 - 250.000 | 50 - 250.000 | 20.000 - 240.000 | 5 - 5.000 | 5 - 20.000 | 1 - 40 | 1 - 250 |
| **overall effi-ciency [%]** | up to 90 | up to 85 | up to 90 | up to 90 | up to 90 | up to 85 | up to 90 |
| **electrical effi-ciency [%]** | 15 - 25 | 25 - 30 | 30 - 45 | 25 - 42 | 28 - 44 | 10 - 30 | 30 - 47 |
| **CHP coefficient** | 0,1 - 0,4 | 0,3 - 0,6 | 0,4 - 1,0 | 0,4 - 1,1 | 0,5 - 1,1 | 0,1 - 0,4 | 0,3 - 2,4 |
| **part load behaviour** | good | suboptimal | suboptimal | good | good | suboptimal | excellent |
| **state of the art** | approved | approved | approved | approved | approved | small range | pilot plants |
| **common fuel** | carbon, waste | natural gas, diesel | natural gas (carbon) | natural gas | diesel (natural gas) | natural gas, wood | natural gas |

Table 1: Comparison of common cogeneration technologies [6, 9]

## 3.2 Application of a CHP unit

A CHP unit consists of an encapsulated combustion engine at about 1,500 rpm, which generates electricity by a generator. Lost heat and engine cooling is used for the heating of water. [6] It is common to use fossil fuels such as natural gas or diesel / fuel oil. If available, the operation with biogas or biodiesel is equally possible.

Cogeneration in general is suitable for real estate of the public authorities such as hospitals, (indoor) swimming pools, for industrial and commercial real estate as well as residential property. Local heating networks in residential areas are often implemented by residential building cooperatives to provide a low cost energy package to their tenants.
Whether CHP can be use has to be verified first. Besides a constant demand for electricity, a property must have an increased requirement for heating or process heat so that the waste heat from power generation in the CHP can be used. Without heat load, efficiency drops to the electricity share. Cooling systems can be set up starting at 10 kW cooling power by a heat pump driven absorption chiller. [6]

A CHP plant is to be dimensioned at about 30% of the maximum necessary thermal energy and can be combined to multiple modules. To avoid inefficient and wear-promoting part load operation time, dimensioning has to be as accurate as possible. Buffer storage helps on fluctuation in demand of heat. [6, 7] A CHP unit doesn't replace the entire existing heating installation since a peak load boiler is required.

With regard to the operation modes, there exist two variations distinguished by the economic point of view. Being *power-operated*, a possible surplus of produced electricity will be feeded to the outside energy grid at an agreed rate. This implies electricity consuming times being notably cost-effective, because generating electricity locally avoids having to buy expensive electricity elsewhere. However, this mode forces the CHP unit to run continuously, having to be cooled when heat consumption is low. Fig. 3 shows the example of a more common *heat led* system. The base load is the defining parameter, there are two modules installed. Requiring more energy than base load, the second CHP unit will be engaged and furthermore, power of the peak load boiler may be added. [7, 10]

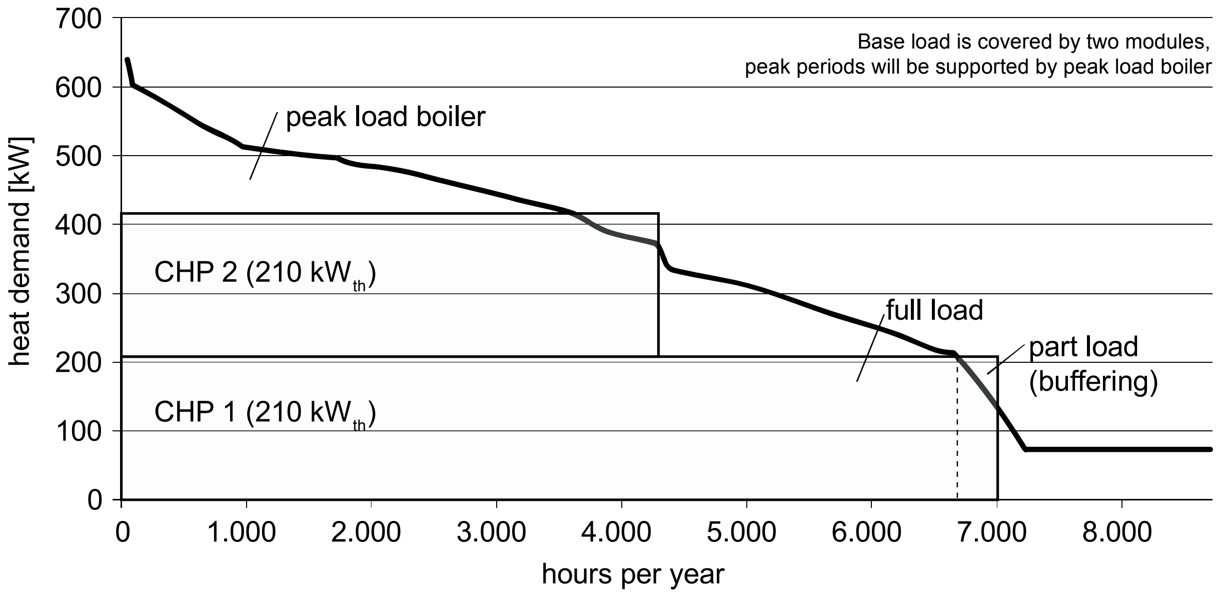


Figure 3: Annual load duration curve of power to be provided (example, heat led) [7]

Establishing a CHP in Germany generally doesn't require an approval, provided that the performance is below 50 kW and emission limit values comply to emission standard "TA-Luft". The CHP has to be registered at the local energy provider in order to feed electricity into its power grid. [11]

## 3.3 Obstacles and prospects

The existing dilemma of investor and users often prevents change of the energetic situation of a let property. Usually the heating costs are part of operating costs being passed to the tenant. For the owner they are transitory items in terms of efficiency of the heating installation and generated costs due to consumption. The investor's priority of modernisation therefore is rather low. The user, however, has to suspect rising rents when modernization measures take place. This is prevalent especially in residential property, where a transfer of the cost of modernization in Germany is limited by the heavily regulated tenancy lay on a yearly ratio of 11% of the rent. Decreasing running costs, however, have to be set off. Commercial tenants are subject to freedom of contract. Due to guaranteed diminishing service charges, both kinds of tenants tenant should benefit from such measures.

The dilemma mentioned above can only be solved by exercising a certain amount of force. Therefore, German law requires replacement of most boilers being installed before 1 October 1978. Basically, such a modernization has to be cost-effective. [12, 13]

The operation of a heating plant has to be energy-saving. Service and maintenance have to be accomplished by specialized personnel. [13] The janitor therefore needs special training, otherwise external service provider might be preferred (outsourcing).

# 4 Operating models

## 4.1 Self-supply

CHP plants can be installed and run by the owner (including a community of owners or a tenant community). Being a modernization measure, an owner may increase the rents. Being free to choose their electricity supplier, tenants have to be offered suitable conditions for locally generated electricity. Costs are calculated based on maintenance and fuel costs.

## 4.2 Contracting / Outsourcing

“Contracting” (familiar in Germany) means to hand over energetic management duties of the owner to an external service provider. However, this comprehensive service is provided on the property or within the real estate of the owner. The transformed structure of ownership, duties and remuneration of the service provider is part of the agreement between owner and contractor. [14] Contracting is applied by municipal administrations, at commercial real estate and residential property, especially by proprietors with a multitude of accommodation units.

Performance scales assumed by the contractor are planning, financing, and optimization of energetic installations. Depending on the service level agreement, variations are delivery of energy, energy saving as well as the acquisition of financing or simply operation of the energetic facilities. Property owners should compare total costs of outsourcing and the case of conducting works themselves. E.g. investing in energy consulting, staff training instead of creating expenses for the contractor’s benefit is usually more profitable in the long run.

# 5 Economic considerations

## 5.1 Cost items

Initial investment in a CHP unit may be treated during a machine life of from 40,000 – 60,000 operating hours (10-15 years) with annuity. Amortisation then takes place within 10 years. In Germany, several subsidiary programs are supportive: e.g. KfW (business development bank) awards grants and loans or investment aids from BAFA (Bundesamt für Wirtschaft und Ausfuhrkontrolle): 50 EUR/ $kWh_{el}$.

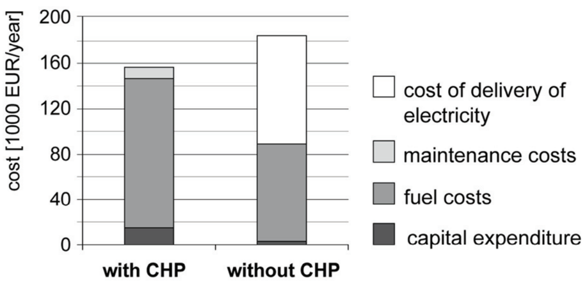


Figure 3: cost allocation (example) [6]

The ongoing consumption-bound cost of fuels (often natural gas) usually consists of a base price, as well as a volume-dependent portion. Tax share of petroleum tax is refunded (0.55 ct/$kWh_{Ho}$ or 0.33 ct/$kWh_{Ho}$ in a commercial environment). [6, 11]

Operating expenses are caused by the operation and maintenance of the plant. They differ depending on the intensity (2.2 - 3.6 ct/$kWh_{el}$ [plant up to 30 $kWh_{el}$]), installations over 200 $kW_{el}$ can be estimated at 1.4 ct / $kWh_{el}$. [11] Miscellaneous costs depend on the level of automation (additional charge of 0,5 – 1,5 %). [6]

## 5.2 Allowances and compensations

In 2009, German government substantiated several national acts concerning their application, e.g. the integrated energy and climate programme. A goal is to double the share of electricity produced by cogeneration from 12% today to 25% by 2020. The CHP act obliges operators to connect decentralised plants to their grid and forces provider to purchase electricity from cogeneration. Operators of CHP plants receive a graduated surcharge on their electricity produced (Tab. 2).

| **class** | **supportive payment** | **duration** | **max. of full load hours** |
|---|---|---|---|
| <= 50 $kW_{el}$ | 5,11 ct/kWh | 10 years | not limited |
| > 50 $kW_{el}$ – 2 $MW_{el}$ | 2,1 ct/kWh | 6 years | 30.000 h |
| > 2 $MW_{el}$ | 1,5 ct/kWh | 6 years | |
| Industry and manufacturing | 1,5 ct/kWh | 4 yeary | |

Table 2: Supportive measures of CHP act (“KWK-Gesetz”) – additional fees

Amendments of renewable energy sources act (“EEG”) will adjust the current proportion of eco power from 13% to 20 – 30% by the year 2020, obligating providers to purchase this electricity with priority. By law, depending on the plant performance, the minimum payment is 9 – 13 ct/kWh. Using biogas, there is a technology bonus of 3 ct/kWh and innovative plant technology (Stirling engine, fuel cell, etc.) may benefit of another 2 ct/kWh encouraging to use these new technologies. The “EEG” levy is charged on top of everyone’s electricity price.

## 5.3 Payback period

The total costs are calculated from electricity production less capital expenses, fuel and maintenance costs. Being 0.55 ct/kWh lower than fuel cost for the ordinary boiler, CHP has an additional advantage. Produced electricity of cogeneration is generally funded (see tab. 2). Additional compensations aggregate to 5-7 ct/kWh for feeding electricity to the power grid. If no external electricity is involved, savings total up to 7-20 ct/kWh. In addition, tax savings in the use of natural gas or renewable energy sources are added.

A CHP plant is repaid, depending on the class, in 10-20 years. If all funding opportunities mentioned above are taken into account, it repays in approx. 7-15 years. [7]

## 6 Subject of Research

Within this paper, it was demonstrated that using a CHP plant the heating system can be adapted to be less dependent from the energy grid besides reducing $CO_2$ emissions and wasting less primary energy and thus contribute to climate protection. Future developments such as the fuel cell promise even higher efficiency and raise hope of a use of cogeneration technology on a large scale. Subsidiary measures on the one hand and a fast payback time with a high reliability of the CHP systems are convincing.

However, further research is to be done. A potential proceeding might be:

- Analyse CHP installations in different locations and on an international basis
- Investigation of a combination with other (renewable) technologies, such as photovoltaic, geothermal energy, et cetera
- In-depth analysis of installation costs
- Setting up a systematic for replacing existing heating installations by comparing various alternatives identifying the optimal solution in order to generate benefit for both property owners and tenants.

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