# Energy Audit Summary Report

# *AEE INTEC*

## Audit no. *15* – UK05

## *Higher Education*

## *University Buildings*


14th of November 2011

Supported by INTELLIGENT ENERGY EUROPE

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# AUDIT n. 15 – UK05

## 1. Data of the auditor

### 1.1. Contact data of the auditor

Name: Matthäus Hubmann
Organisation: AEE INTEC
Country: Austria
Profession: engineer
Number of audits performed: 1
Date of the audit: 14/11/2011
Duration of the audit: 4 weeks

## 2. Introduction

### 2.1. Objectives

The objectives of the audit are the modelling of the present state, the calculation of the energy consumption (total and process split) and furthermore the recognition possible changes in the energy supply.

## 3. Status Quo: processes, distribution, energy supply

### 3.1. General info of company

| | |
|---|---|
| Name: | The University of Warwick |
| Location: | Warwick, Coventry, UK |
| Sector: | Higher Education |
| Number of employees: | n.a. |
| Number of students: | 22,677 |

The University has benefitted from the installation of a gas powered Combined Heat & Power plant (CHP), which generates electricity (26,052 MWh/a) and uses by-product heat (39,597 MWh/a) to supply the University's district heating system.
The University has committed to achieving a significant reduction in carbon emissions by 2020. These drivers all indicate a need for the University to invest in further heat supplying capacity including a reduction of $CO_2$ emissions.

3.2. Flow sheet of the whole manufacturing side (processes, distribution, energy supply) in form of a block diagram

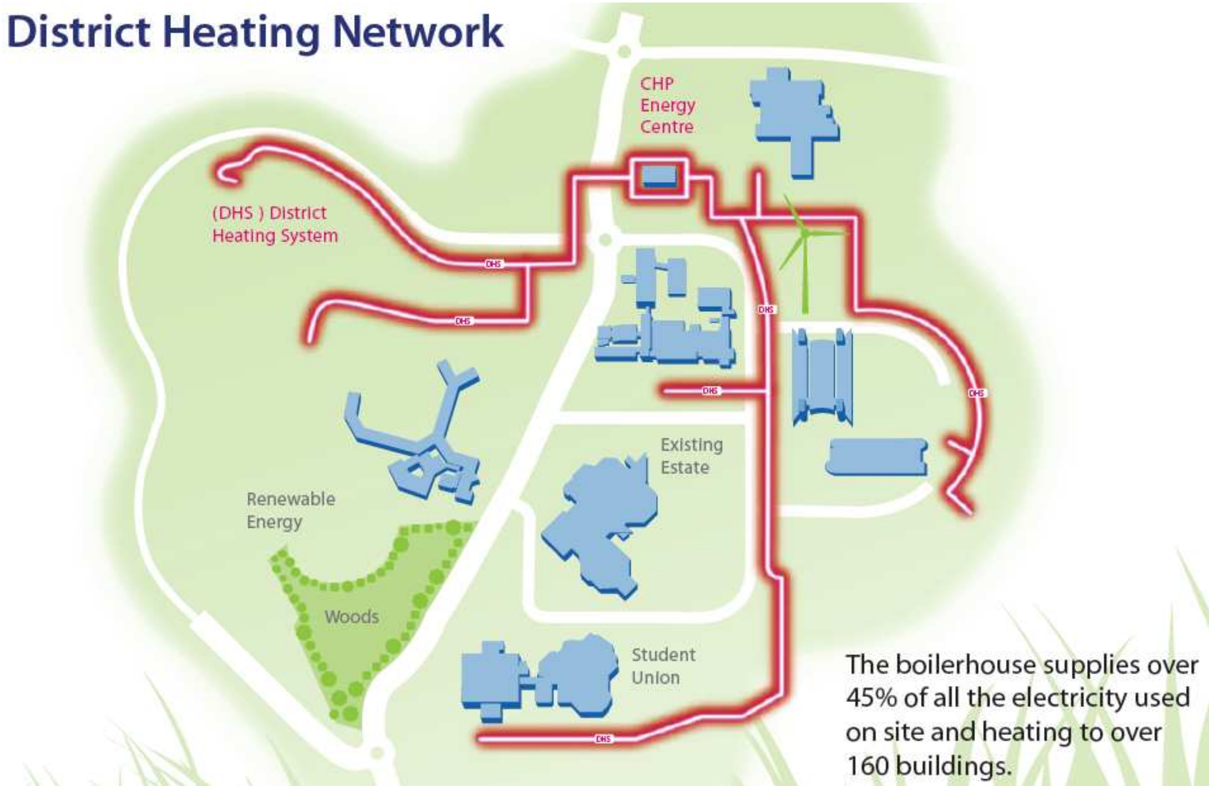


**Figure 1: District Heating Network of the university**

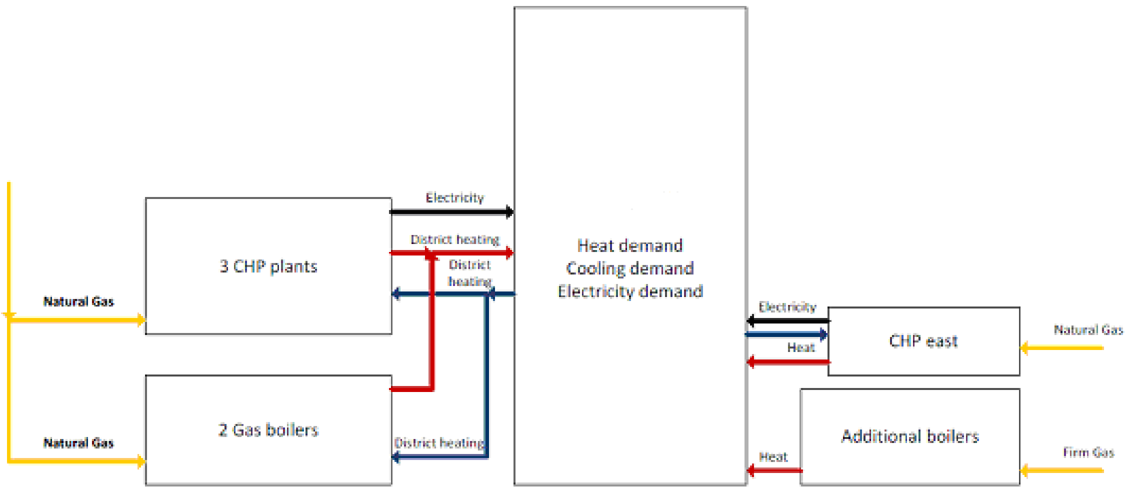


**Figure 2: Flow sheet of the energy supply**

## 3.3. Description of the existing system

- Energy Supply is shows in the Figure 2: Flow sheet of the energy supply.

**Primary energy consumption:**

**Table 1:** **Total primary energy consumption (PEC) and primary energy consumption for thermal use (PET)**

| Energy type (fuels / electricity) | PEC | | PET | |
|---|---|---|---|---|
| | [MWh] | [% of Total] | [MWh] | [% of Total] |
| Total fuels | 151,640 | 63.66 | 152,304 | 219.98 |
| Total electricity | 86,571 | 36.34 | -83,068 | -119.98 |
| **Total (fuels + electricity)** | **238,211** | **100.00** | **69,236** | **100.00** |

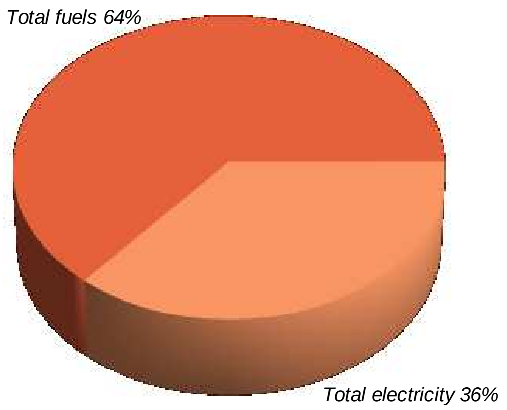


**Figure 3:** **Distribution of PEC by fuel type**

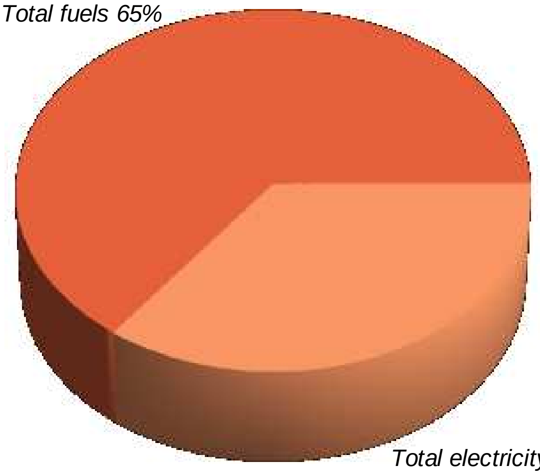


**Figure 4: Distribution of PET by fuel type**

Final energy consumption (FEC) per fuel, final energy demand thermal (FET):

**Table 2: Total final energy consumption (FEC) and final energy for thermal use (FET); present state.**

| Fuel type | FEC | | FET | |
|---|---|---|---|---|
| | [MWh] | [% of Total] | [MWh] | [% of Total] |
| Natural gas | 91,965 | 55.16 | 91,965 | 83.02 |
| firm gas | 45,889 | 27.53 | 46,493 | 41.97 |
| Electricity | 28,857 | 17.31 | -27,689 | -25.00 |
| **Total** | 166,711 | 100.00 | 110,769 | 100.00 |

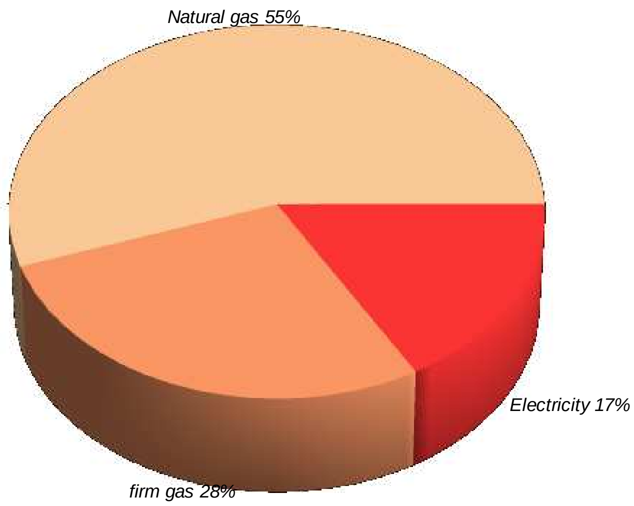


**Figure 5: Total final energy consumption for thermal use (FET); present state.**

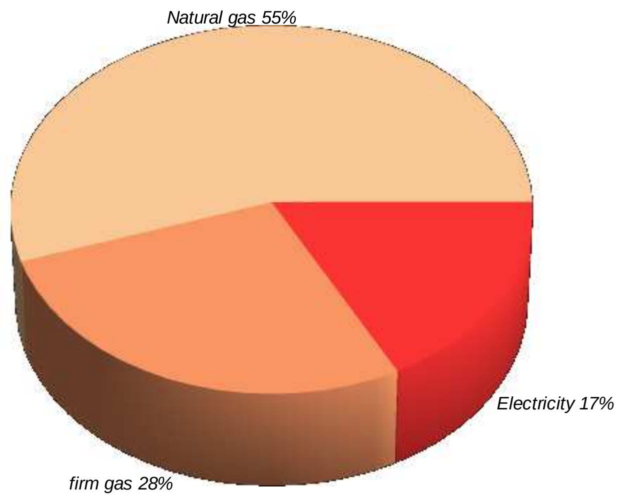


**Figure 6: Total final energy consumption (FEC); present state.**

**Table 3: Final energy consumption for thermal use (FET) by equipment (present state).**

| Equipment | Fuel type | FET by equipment [MWh] | FET by equipment [% of Total] |
|---|---|---|---|
| CHP 1 | Natural gas(- gen.elect.) | 18,553 | 16.94 |
| CHP 2 | Natural gas(- gen.elect.) | 18,553 | 16.94 |
| CHP 3 | Natural gas(- gen.elect.) | 18,553 | 16.94 |
| Gas boiler 1 | Natural gas | 1,233 | 1.13 |
| Gas boiler 2 | Natural gas | 1,240 | 1.13 |
| additional boilers | firm gas | 46,988 | 42.90 |
| medium cooling | Electricity | 162 | 0.15 |
| small cooling | Electricity | 175 | 0.16 |
| chiller | Electricity | 8 | 0.01 |
| CHP east | Natural gas(- gen.elect.) | 4,055 | 3.70 |
| **Total** | | **109,520** | **100.00** |

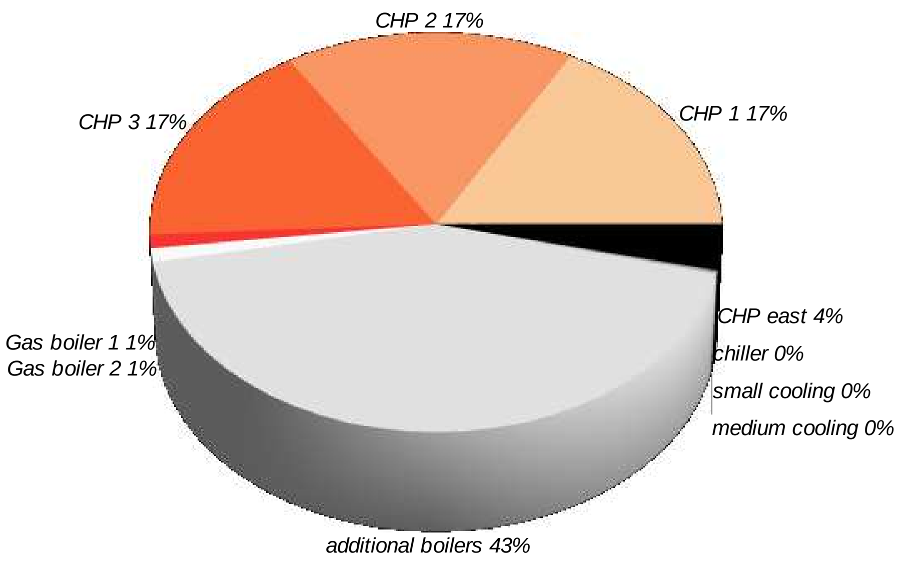


**Figure 7: Final energy consumption for thermal use (FET) by equipment**

Useful supply heat (USH), Fuel and electricity demand:

**Table 4: supply heat (USH) by equipment. Present state.**

| Equipment | USH by equipment | |
|---|---|---|
| | [MWh] | [% of Total] |
| CHP 1 | 12,812 | 15.33 |
| CHP 2 | 12,812 | 15.33 |
| CHP 3 | 12,812 | 15.33 |
| Gas boiler 1 | 1,533 | 1.83 |
| Gas boiler 2 | 1,576 | 1.89 |
| additional boilers | 39,242 | 46.95 |
| CHP east | 2,803 | 3.35 |
| **Total** | **83,591** | **100.00** |

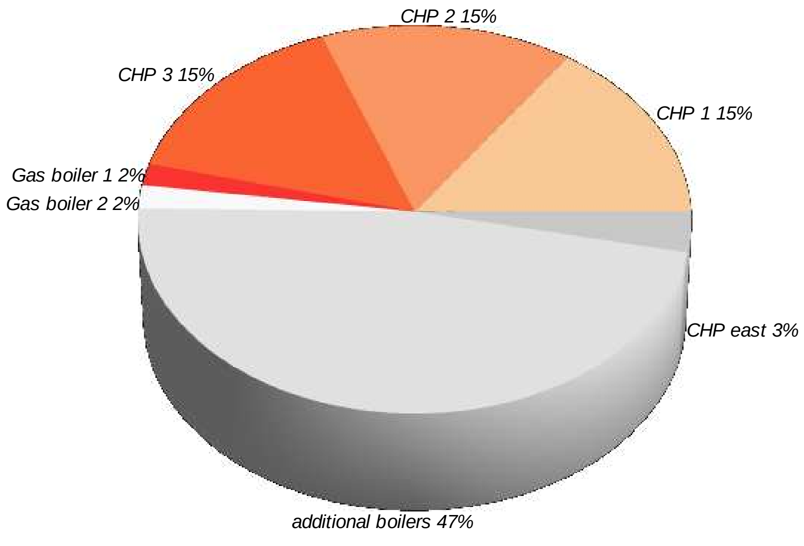


**Figure 8: Useful supply heat (USH) by equipment. Present state.**

**Table 5: Useful supply cooling (USC) by equipment; present state.**

| Equipment | USC by equipment | |
|---|---|---|
| | [MWh] | [% of Total] |
| medium cooling | 389 | 26.19 |
| small cooling | 389 | 26.18 |
| chiller | 707 | 47.63 |
| **Total** | **1,484** | **100.00** |

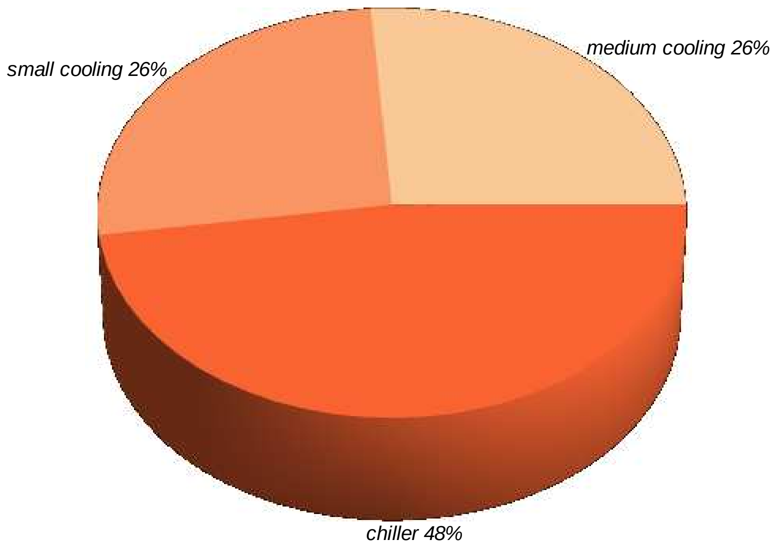


**Figure 9: Useful supply cooling (USC) by equipment. Present state.**

- Distribution system

Media and temperatures

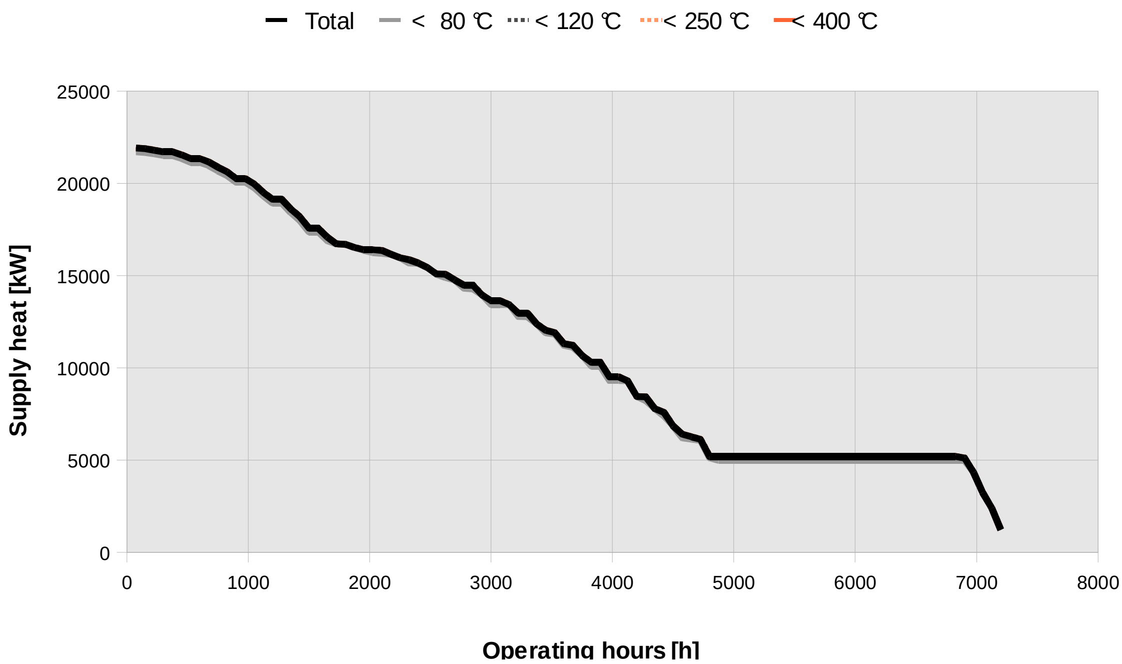


**Figure 10: Distribution of supply heat by temperature levels and annual operating hours. Present state.**

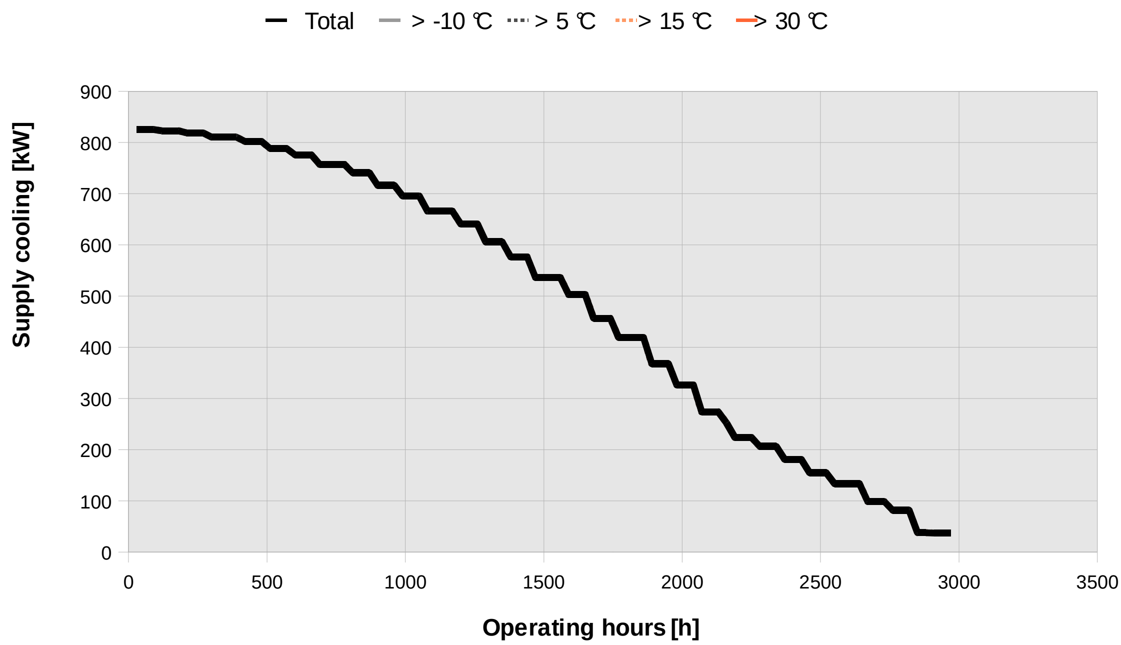


**Figure 11: Distribution of supply cooling by temperature levels and annual operating hours. Present state.**

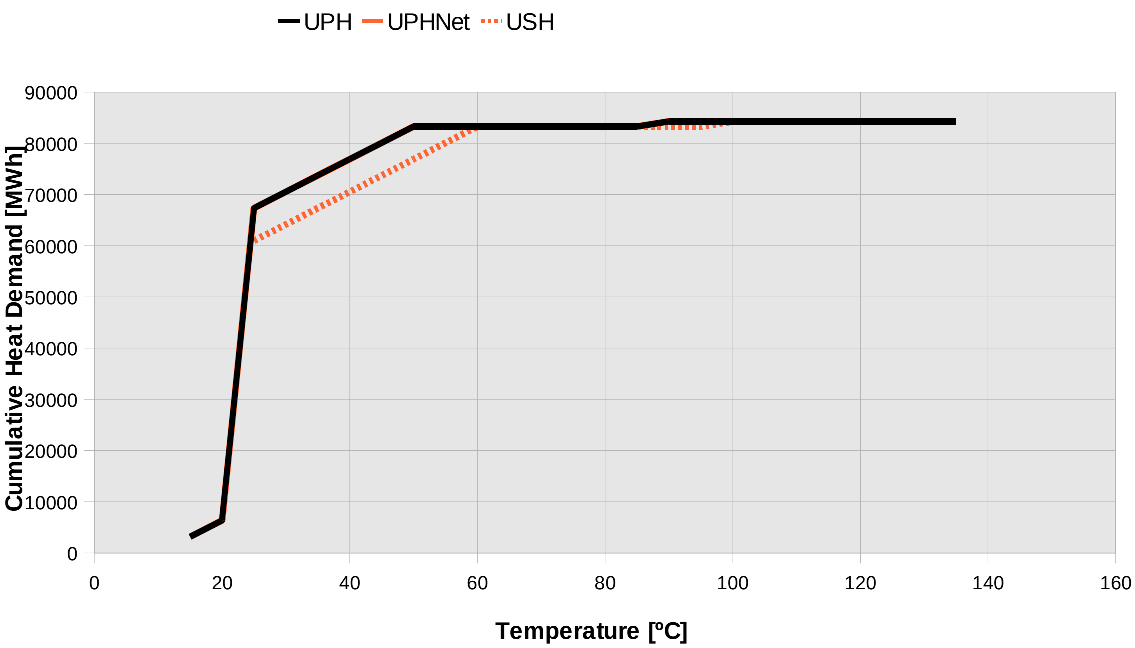


**Figure 12: Distribution of the heat demand by temperature levels**

- Main energy consuming energy processes and buildings
  External energy delivered to process (UPHproc), Total energy demand (UPH) per process

**Table 6: Useful process heat demand (UPH) by process. Present state**

| Process | Total [MWh] | Circulation [MWh] | Maintenance [MWh] | Start-up [MWh] |
|---|---|---|---|---|
| all buildings_HW | 24,792 | 24,792 | 0 | 0 |
| all buildings_heating | 57,780 | 0 | 57,780 | 0 |
| heat demand chiller | 1,019 | 0 | 1,019 | 0 |
| Total | **83,591** | | | |

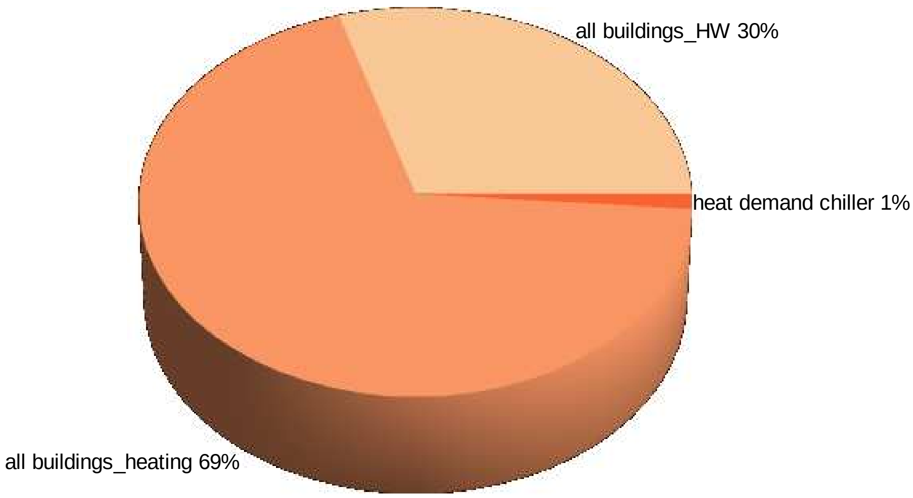


**Figure 13: Useful process heat (UPH) by process**

**Table 7:** **Useful process cooling demand (UPC) by process. Present state.**

| Process | Total<br>[MWh] | Circulation<br>[MWh] | Maintenance<br>[MWh] | Start-up<br>[MWh] |
|---|---|---|---|---|
| all buildings_cooling | 770 | 0 | 770 | 0 |
| math building_cooling | 399 | 0 | 399 | 0 |
| WBS building_cooling | 308 | 0 | 308 | 0 |
| Total | **1,477** | | | |

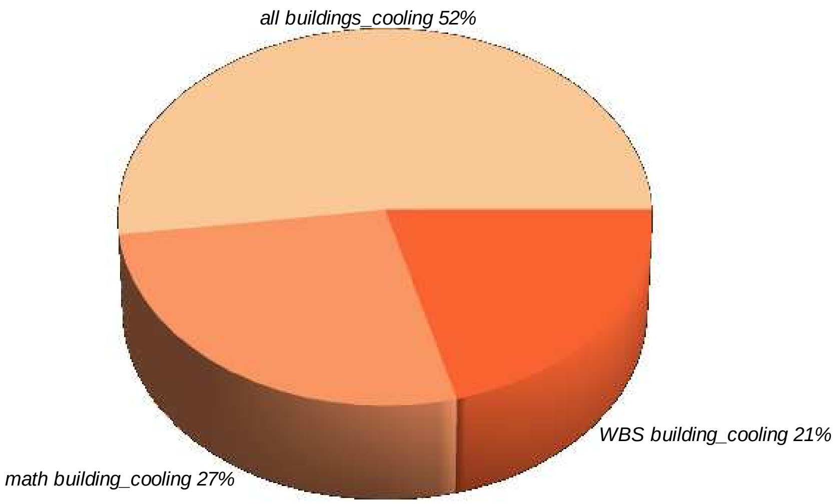


**Figure 14: Useful process cooling (UPC) by process**

3.4. General

- As only data of 3 month for the heat demand of the absorption chillers was available the heat/cooling demand was extended to 5 month and led to a total heat demand of 1,019 MWh per year (math: 399 MWh/a; WBS: 308 MWh/a).
- The average hot water consumption was calculated of the month June, July and August by the total heat consumption minus 3 % of losses in the district heating system and minus the heat demand of the absorption chillers during this month, which resulted in a water consumption of 1,000 to 1,740 m³/day. Taking the yearly water consumption in account an average of 1,573m³ of water per day was calculated. An assumption was made than that per day 1,500 m³ of hot water are needed.
- The heating demand was than calculated from the heat consumption (district heating and the local boilers) minus the absorption chiller demand and the hot water heat demand (57,780 MWh).
- The cooling demand was assumed according to the heat demand of 126 kWh/m²a which led to a cooling demand of 1,68 kWh/m²a and resulted in a total cooling demand of 770 MWh.

# 4. Comparative study

**Table 8: Overview of the alternative proposals studied**

| Short Name | Description |
|---|---|
| solar 5,000 m² | based on present state + 20,000 m² solar thermal supply system |
| CHP biomass | based on present state + CHP (combined heat and power) with wood chips |

## 4.1. Proposed alternative: **solar 20,000 m²**

- Solar 20,000 m²; available surface: 20,000 m²

| | |
|---|---|
| Collector type: | FPC (flat plate collector) |
| Installed capacity: | 3,725 kW |
| Installed collector area: | 5,321 m² |
| Solar buffer storage volume: | 266 m³ |
| Solar fraction: | 2.13 % |
| Annual energy yield: | kWh/kWa |
| Contribution to heat supply: | 1,795 MWh/a |

A solar thermal collector field of 5,321 m² is installed and contributes 1,795 MWh of thermal energy to the district heating system.

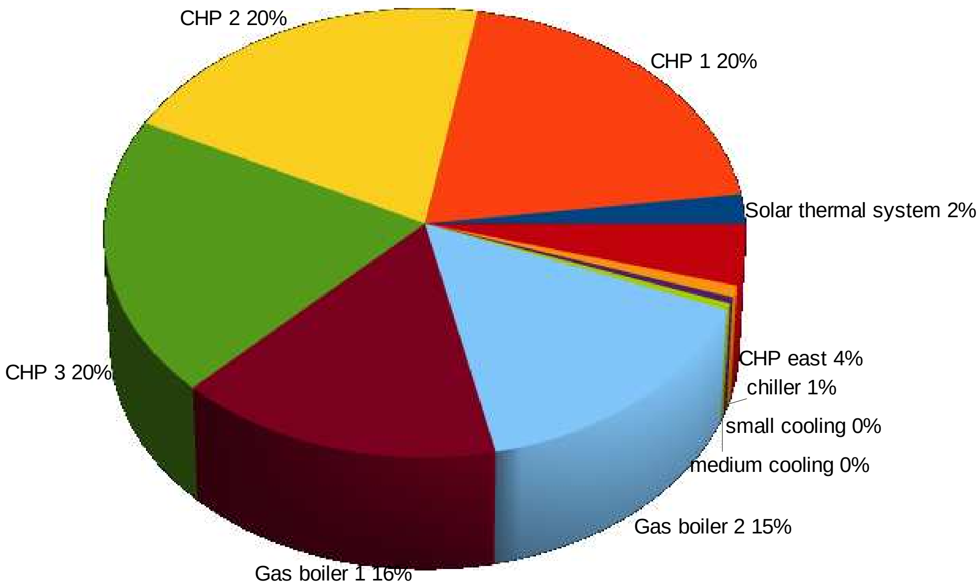


**Figure 15: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).**

**Table 9:** **Heat and cooling supply equipment and contribution to total heat and cooling supply**

| Equipment | Type | Heat and cooling supplied to pipe/duct | Nominal capacity | Contribution to total heat and cooling supply | |
|---|---|---|---|---|---|
| | | | [kW] | [MWh] | [%] |
| Solar thermal system | solar thermal (flat-plate) | o==district heating==o | 3,725 | 1,795 | 2.11 |
| CHP 1 | CHP gas turbine | o==district heating==o | 2,060 | 17,143 | 20.15 |
| CHP 2 | CHP gas turbine | o==district heating==o | 2,060 | 17,143 | 20.15 |
| CHP 3 | CHP gas turbine | o==district heating==o | 2,060 | 17,143 | 20.15 |
| Gas boiler 1 | hot water boiler | o==district heating==o | 5,000 | 13,471 | 15.83 |
| Gas boiler 2 | hot water boiler | o==district heating==o | 5,000 | 13,144 | 15.45 |
| additional boilers | hot water boiler | o==district heating==o | 13,865 | 0 | 0.00 |
| medium cooling | compression chiller (air cooled) | o==distribution cooling==o | 2,020 | 389 | 0.46 |
| small cooling | compression chiller (air cooled) | o==distribution cooling==o | 2,677 | 389 | 0.46 |
| chiller | compression chiller (air cooled) | o==cooling math building==o o==cooling WBS building==o | 1,200 | 707 | 0.83 |
| CHP east | CHP gas turbine | o==district heating==o | 2,000 | 3,751 | 4.41 |
| **Total** | | | **41,667** | **85,076** | **100** |

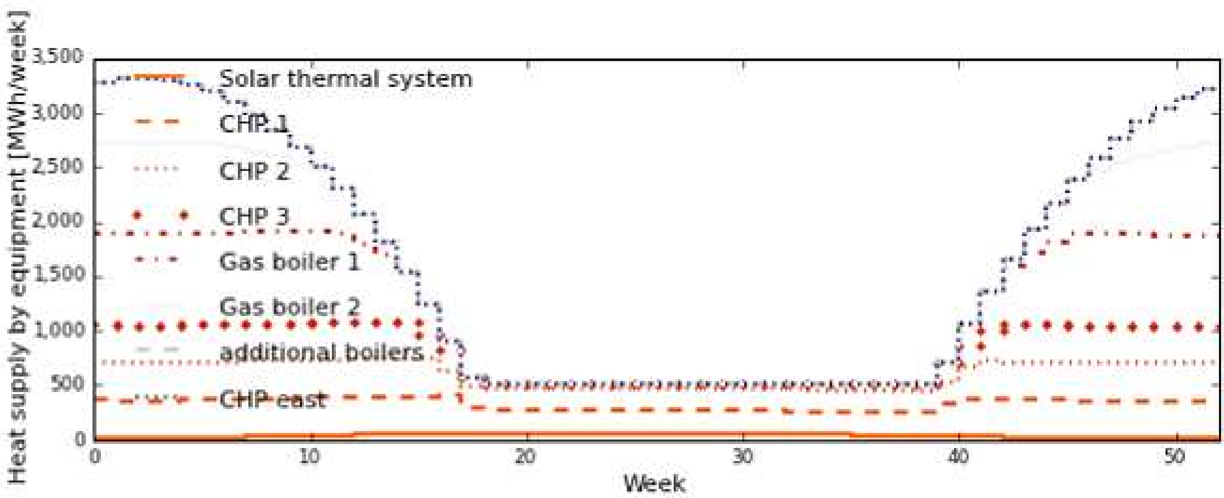


**Figure 16: Weekly heat supply by equipment**

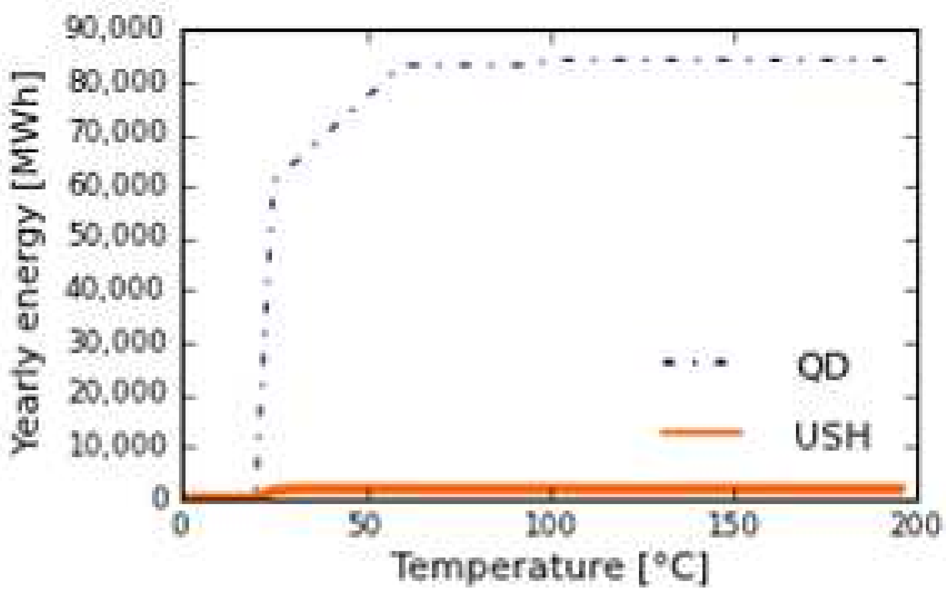


**Figure 17: Heat demand and solar contribution**

4.2. Proposed alternatives: **CHP biomass**

- CHP biomass

| | |
|---|---|
| CHP type: | ORC (Organic Rankine Cycle) |
| Biomass type: | wood chips (LHV: 4 KWh/kg) |
| Installed thermal capacity: | 1,000 kW |
| Installed electrical capacity: | 250 kW |
| Thermal efficiency: | 0.72 |
| Electrical efficiency: | 0.18 |
| Operating hours: | 8,584 |

The heat supply for the ORC plant is delivered by a burner fed with wood chips with a lower heating value of 4 kWh/kg. The overall electric efficiency, including the wood furnace, is assumed by 18 % and the thermal efficiency of the whole plant is assumed by 72 %.

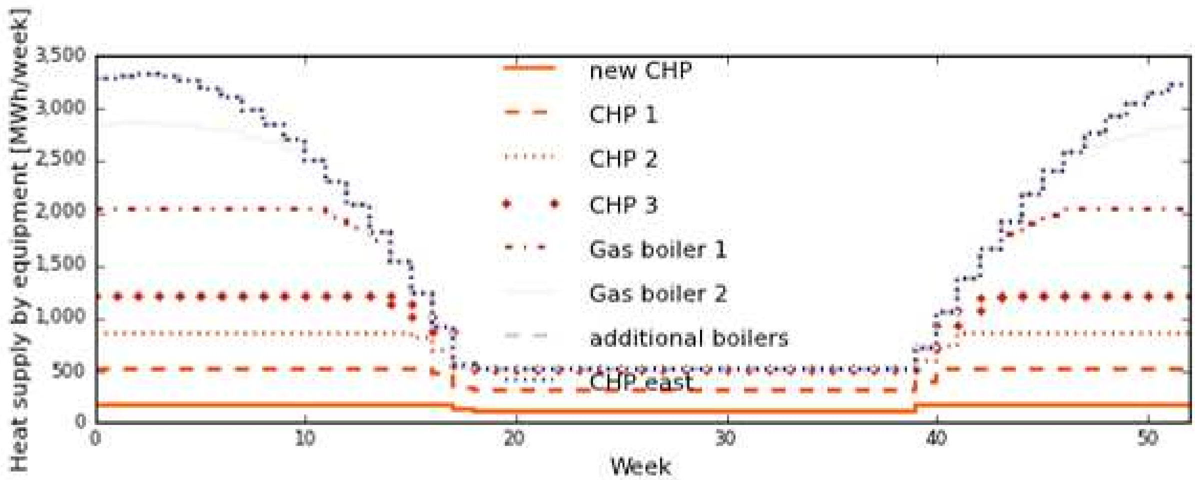


**Figure 18: Weekly heat supply by equipment**

**Table 10:** **Heat and cooling supply equipment and contribution to total heat and cooling supply**

| Equipment | Type | Heat and cooling supplied to pipe/duct | Nominal capacity | Contribution to total heat and cooling supply | |
|---|---|---|---|---|---|
| | | | [kW] | [MWh] | [%] |
| new CHP | CHP engine | o==district heating==o | 1,000 | 8,322 | 9.78 |
| CHP 1 | CHP gas turbine | o==district heating==o | 2,060 | 17,143 | 20.15 |
| CHP 2 | CHP gas turbine | o==district heating==o | 2,060 | 17,143 | 20.15 |
| CHP 3 | CHP gas turbine | o==district heating==o | 2,060 | 17,143 | 20.15 |
| Gas boiler 1 | hot water boiler | o==district heating==o | 5,000 | 10,074 | 11.84 |
| Gas boiler 2 | hot water boiler | o==district heating==o | 5,000 | 10,014 | 11.77 |
| additional boilers | hot water boiler | o==district heating==o | 13,865 | 0 | 0.00 |
| medium cooling | compression chiller (air cooled) | o==distribution cooling==o | 2,020 | 385 | 0.45 |
| small cooling | compression chiller (air cooled) | o==distribution cooling==o | 2,677 | 385 | 0.45 |
| chiller | compression chiller (air cooled) | o==cooling math building==o o==cooling WBS building==o | 1,200 | 707 | 0.83 |
| CHP east | CHP gas turbine | o==district heating==o | 2,000 | 3,751 | 4.41 |
| **Total** | | | **38,942** | **85,068** | **100** |

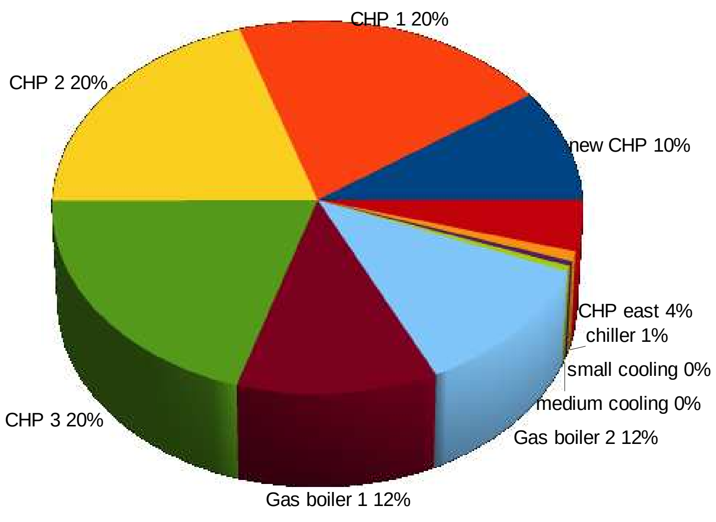


**Figure 19: Contribution of each equipment to the total useful heat and useful cooling supply (USH & USC).**

# 5. Selected alternative(s) and conclusions

## 5.1. Selected alternative: CHP biomass

Based on the primary energy savings of 11 % the second alternative "CHP biomass" is selected as best solution. In addition the selected alternative has a shorter payback period compared to the first alternative.

**Table 11:** **Primary energy consumption: present state and alternative proposals**

| Alternative | Primary energy consumption | Savings | |
|---|---|---|---|
| | [MWh] | [MWh] | [%] |
| Present State (checked) | 238,802 | --- | --- |
| solar 5,000 m² | 221,735 | 17,067 | 7.15 |
| CHP biomass | 212,826 | 25,976 | 10.88 |

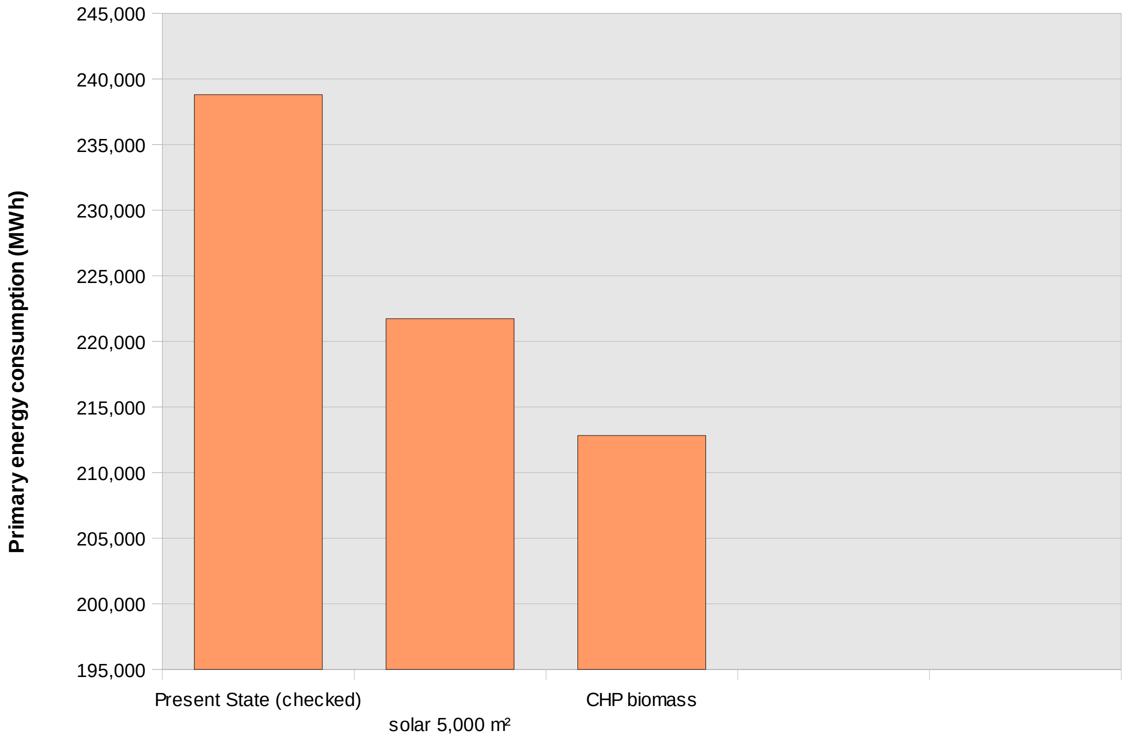


**Figure 20:** **Primary energy consumption: present state and alternative proposals**

### 5.1.1. Process optimisation (written proposals)

Based on the available data no process optimisation was proposed.

### 5.1.2. Heat recovery

Based on the available data no process optimisation was proposed.

### 5.1.3. Heat and Cold Supply

| | |
|---|---|
| CHP type: | ORC (Organic Rankine Cycle) |
| Biomass type: | wood chips (LHV: 4 KWh/kg) |
| Installed thermal capacity: | 1,000 kW |
| Installed electrical capacity: | 250 kW |
| Thermal efficiency: | 0.72 |
| Electrical efficiency: | 0.18 |
| Operating hours: | 8,584 |

## 5.2. Comparative study and conclusions

**Table 12: Comparative study**

| | | Present state | Alternative | Saving |
|---|---|---|---|---|
| Total primary energy consumption (1) | [MWh] | 238,802 | 212,826 | 25,977 |
| Allocation of energy consumption | [-] | | | |
| Total fuels | [MWh] | 152,231 | 160,922 | - 8,691 |
| Total electricity | [MWh] | 86,571 | 51,903 | 34,668 |
| Share of renewable energy | [%] | | 5 | |
| $CO_2$ emissions | [tons/a] | 48,892 | 43,574 | 5,318 |
| Annual energy system cost (2) | [EUR] | 7,229,934 | 6,143,328 | 1,086,606 |
| Total investment costs | [EUR] | | 1,500,000 | |
| Payback period (3) | [years] | | 2 | |

*(1) including primary energy consumption for non-thermal uses*

*(2) including energy cost (fuel and electricity bills), operation and maintenance costs and annuity of total investment.*

*(3) Supposing 30% of funding of total investment (subsidies or equivalent other support mechanisms)*

- $CO_2$-emission savings chart:

**Table 13: Environmental impact: present state and alternative proposals**

| Alternative | Production of CO2<br>[t] | Water consumption<br>[m3] |
|---|---|---|
| Present State (checked) | 48,892.11 | 0.00 |
| solar 5,000 m² | 45,398.00 | 0.00 |
| CHP biomass | 43,574.00 | 0.00 |

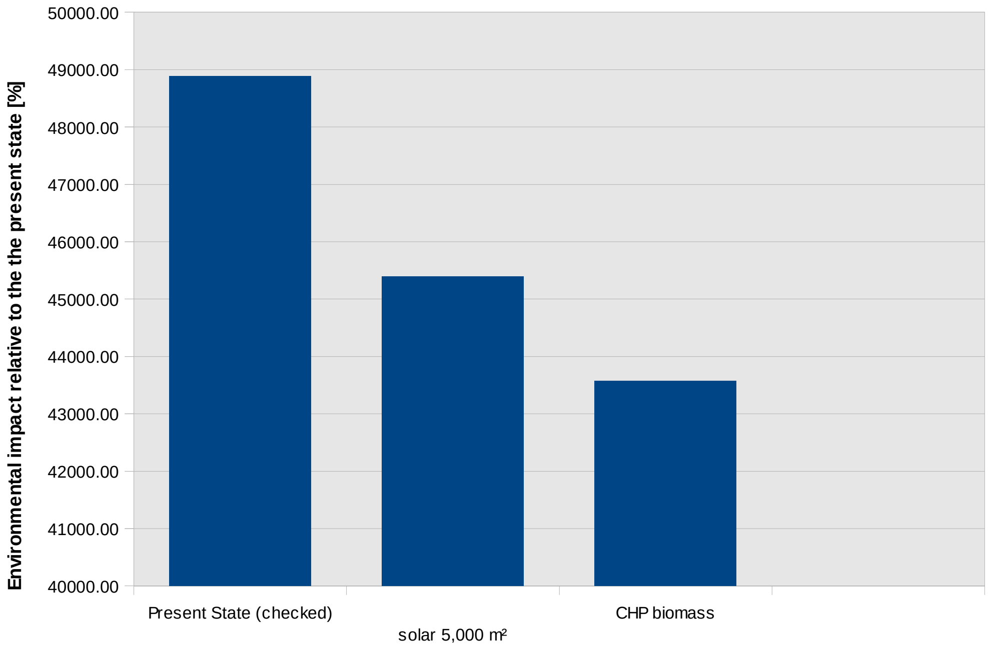


**Figure 21: Comparison of alternatives: environmental impact**

### 5.2.1. Energy and environmental analysis

By installing the ORC plant the primary energy consumption via natural gas can be partly substituted by renewable energy out of wood chips and leads to CO2 savings of 5,318 tons per year.

### 5.2.2. Economic analysis

The investment costs for the CPH plant are assumed by € 1,500,000 and the flat plate collectors by € 1,676,010. The calculated payback period for the alternative "CHP biomass" is therefore 2 years based on a funding rate of 30 %.

**Table 14: Investment cost: alternative proposals**

| Alternative | Total investment [€] | Own investment [€] | Subsidies [€] |
|---|---|---|---|
| Present State (checked) | --- | --- | --- |
| solar 5,000 m² | 1.676.010 | 1.173.207 | 502.803 |
| CHP biomass | 1.500.000 | 1.050.000 | 450.000 |

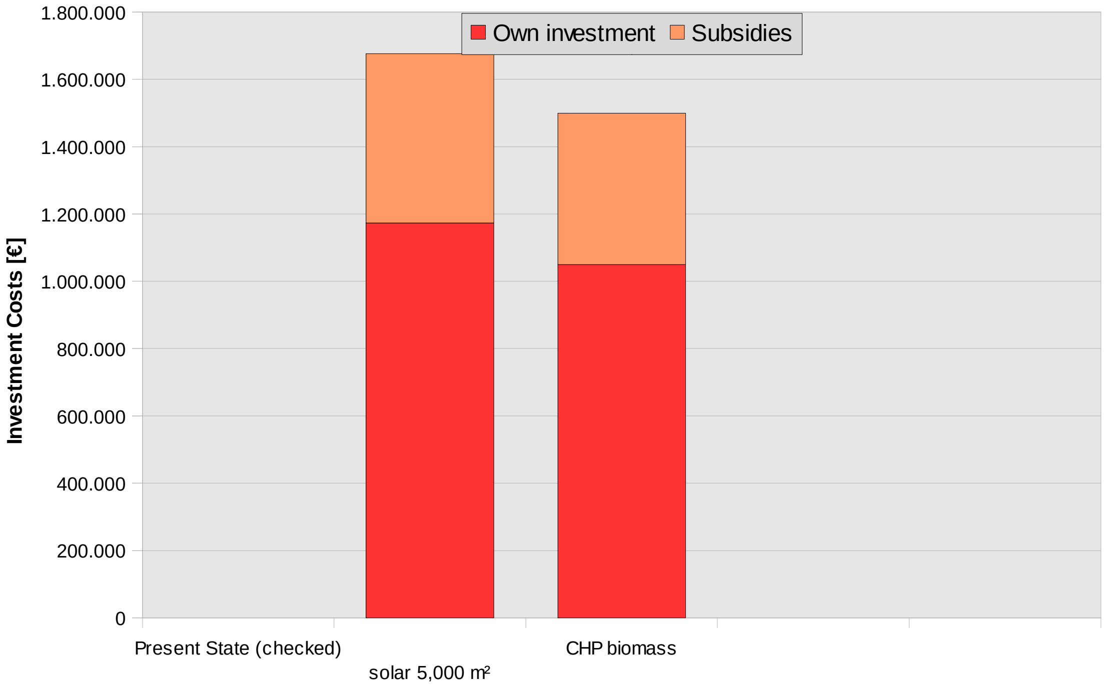


**Figure 22: Comparison of alternatives: Investment cost**

### 5.2.3. Conclusions and outlook

Based on the available data the energy consumption split to the processes and equipments could have been calculated by EINSTEN and the results are well comparable to the present state of the company. For the economic aspects some further calculations will be necessary as the funding rate and the final investment costs are based on first estimations.