Renewable Energies section, June 2005

Efficiency potentials of heat pumps with combined heat and power

For maximum reduction of CO_2 emissions and for electricity generation from fossil fuels with CO_2 reduction in Switzerland

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Report commissioned by:

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Abstract

In Switzerland, approximately 80% of the low-temperature heat required for rooms and for the heating of hot water is produced by burning combustibles. Around a million gas and oil boilers were in use in Switzerland in 2000, and these accounted for approximately half the country's 41.1 million tonnes of CO_2 emissions.

But there is a more efficient solution: the heat pump. Heat pumps take renewable energy from the ground, ground water, rivers, lales and outside air, and bring it up to a usable level. The heat source is constantly renewed through sunlight, precipitation and geothermal energy.

With the enormous potential of our environment it would be possible to replace half the total number of boilers in use today with heat pumps. This would be equivalent to 90 PJ p.a. of useful heat, or 500,000 systems.

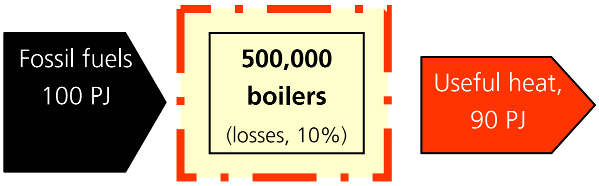

Figure 1: Energy flow of fossil-fuelled boilers

The power source for heat pumps comes from the substitution of electric heating systems and from the substitution of boilers with combined heat and power systems with full heat utilisation. This means that the entire required power source can be provided without the need to construct new electricity production plants.

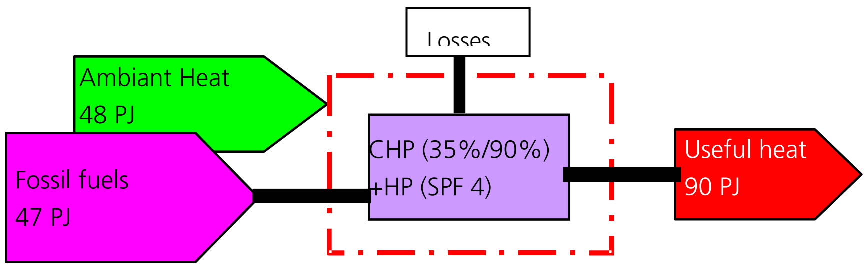

Figure 2: Energy flow for the combination of heat pumps with combined heat and power systems

With electricity from combined heat and power, the use of combustibles is halved, as are CO_2 emissions. Measured against Switzerland's total volume of emissions from combustibles (24.3 million tonnes of CO_2), the reduction would be 5 million tonnes of CO_2, or 21% of the present-day level.

The required power can also be obtained from new co-generation plants, without heat utilisation. In this case, the reduction of combustibles and pollutants is greater than with conventional combined heat and power, and the results are even better with partial or full heat utilisation from co-generation systems.

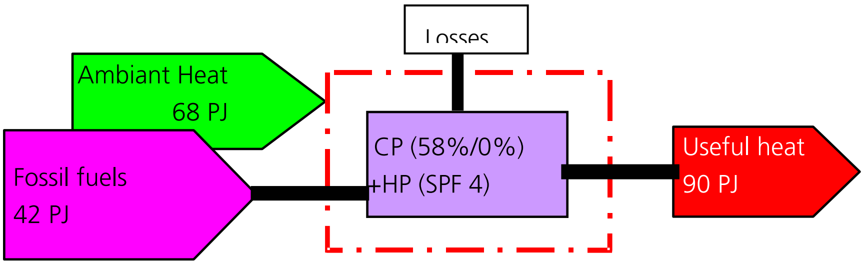

Figure 3: Energy flow for the combination of heat pumps with co-generation plants: the entire power supply drives the heat pump(s).

Another option would be to keep CO_2 emissions constant and generate electricity from fossil sources. Here the volume of CO_2 emissions that is eliminated through the substitution of oil and gas boilers could be used by way of compensation for generating electricity.

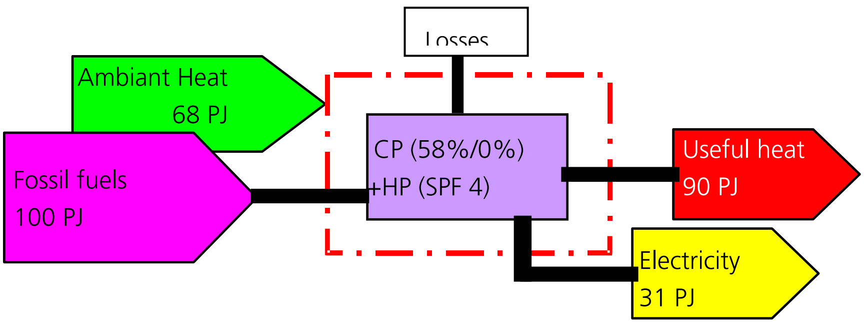

Figure 4: Energy flow for the combination of heat pumps with co-generation plants: 42% of the power supply drives the heat pump(s).

The level of CO_2 emissions remains constant, and 31 PJ p.a. (or 8.6 TWh p.a.) of electricity is produced, which is equivalent to 15% of Switzerland's domestic consumption in 2004.

The table below shows the energy-efficiency potentials and reduction of CO_2 emissions:

Potentials (figures rounded up or down)	Theoretical (natural) potentials	Technical (technological) potentials	Exploitable potentials (realisable by the market) 2050	by 2010
Energy from the environment (PJ p.a.)	>400	176	72	10
Contribution towards SwissEnergy targets (in %)	Potential to meet Switzerland's entire heating requirements several times over!	1630%	712%	93%
Generated useful heat (PJ p.a.)		220	90	14.4
Proportion of useful heat in Switzerland		80%	33%	7%
Net CO_2 reduction (in tonnes)		12,2,000	5,000,000	800,000
Contribution towards reduction of CO_2 emissions from combustibles (in %)		50%	21%	3%
Contribution towards reduction of CO_2 emissions throughout Switzerland (in %)		30%	12%	2%

Table 1: Potentials of Ambiant heat and resulting useful heat produced via heat pumps. Calculations for CO_2 reduction take the production of the required power supply into account.

Converted into numbers of units (figures are potentials, not targets!):

Potentials (figures rounded up or down)	Technical (technological) potentials	Realisable on the market 2050	by 2010
Potential number of heat pumps p.a.	Switzerland's entire heating requirements covered by heat pumps alone	40,000	15,000
Potential market share (year)		80%	30%
Potential number of heat pumps (accumulated)		500,000	130,000
Potential proportion of heat pumps to all heating systems throughout Switzerland		50%	13%

Table 2: Potentials of Ambiant heat and resulting useful heat produced via heat pumps, converted into numbers of units. Calculations for CO_2 reduction take the production of the required power supply into account.

1. Introduction

The potential of the use of ambient heat for producing useful heat via heat pumps has not been updated in recent years [6], or it has only been given minor consideration in comprehensive studies [9], [10]. This report incorporates the latest market trends, technological developments and research findings, and simultaneously deals with potentials for the reduction of CO_2 emissions.

Half the volume of CO_2 emissions in Switzerland is attributable to the production of heat for room heating and hot water, while transport is responsible for one-third. Substitution with other technologies is now immediately possible. For every heating system there are now alternative solutions to boilers available on the market. This study examines the use of heat pumps for heating purposes and/or for the production of hot water.

Around a million gas and oil boilers were in use in Switzerland in 2000, and these accounted for approximately half the country's 41.1 million tonnes of CO_2. As we shall see in chapter 3, the utilisable potential of 90 PJ p.a. attributable to heat pumps is equivalent to approximately 500,000 boilers.

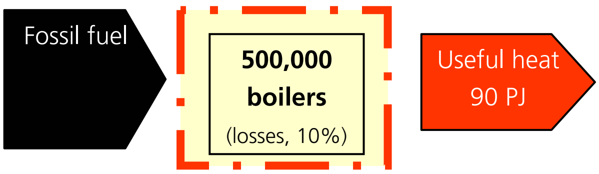

Figure 5: Energy flow of fossil-fuelled boilers

Note: the order of magnitude of the figures and estimates presented below is of significance here. This concerns petajoules (PJ), terawatt hours (TWh) and gigawatt hours (GWh). We have taken the definitions of the various potentials from [15]. By contrast with earlier studies, this report has also set out to convert all energy quantities into numbers of units, but these figures, too, are intended as approximations only. The aim has been to present the abstract and often enormous figures in a readily comprehensible manner.

Since these concern the calculation of potentials, by contrast with perspectives there is no fixed timeframe. The potential itself continues to exist as long as there is still a requirement for room heating and hot water. Potentials are not targets – they show what would be possible, not what has to be attained.

2. Energy potentials

2.1. Theoretical potential

In this study, this term refers to the absolute highest potential, i.e. the level of energy obtainable in accordance with physical laws. In accordance with [7], the potential for Ambiant heat is 43,300 GWh p.a., which is equivalent to 156 PJ p.a. Here it should be noted that this does not take account of the largest source of heat, namely air, and that boreholes heat exchangers as a heat source have been regarded very conservatively.

We have to limit ourselves to those heat sources that are immediately available. In [21] and [9], the availability of all heat sources (the ground, surface water, ground water and waste heat) in the close vicinity of consumers was analysed, with the exception of the outside air. The potentials are 107 TJ for surface water, 18 PJ p.a. for ground water, 18 PJ p.a. for upper level geothermal energy (not yet utilised today), and 26 PJ p.a. for waste water from sewage treatment plants. The overall potential for Ambiant heat (ground, surface water, groundwater, waste water) is thus 169 PJ p.a.

This does not include the outside air, which of course exists everywhere and is an immediately available source of heat. The utilisation of energy from the air takes the form of indirect utilisation of accumulated solar energy. The potential is therefore at least as great as that for solar energy in a built area (cf. [22]), which amounts to more than 300 PJ p.a.

We therefore have a total of around 469 PJ p.a. in Ambiant heat at our disposal, which allows to produce over 1'800PJ of useful heat. But it would "only" need approximately 240 PJ p.a. to cover Switzerland's entire heating requirements. In theory, there is therefore sufficient environmental heat to meet the country's heating requirements many times over!

2.2. Technical potential

The term "technical potential" describes the proportion of the theoretical potential that it is possible to exploit on the basis of the current status of technological development while taking account of the applicable legal requirements (e.g. provisions governing environmental protection and the protection of historical monuments). Here, both the status of technology and legislation are variables that can be changed over the course of time.

The demand for useful heat has been adopted from [1] and [2]. Technically speaking, heat pumps can replace practically every existing heating system. The only limitation here concerns large-scale central-heating systems with flow temperatures above 65° C. A study conducted by the Ecole Polytechnique Fédérale de Lausanne [23] revealed that it would be technically possible to operate approximately 80% of existing heating systems with heat pumps. It is conceivable that in the period between 2008 and 2010, a new generation of heat pumps with CO_2 as refrigerant may be introduced, which will permit a flow temperature of 70° to 90° C. Another type of heat pump is currently coming back into favour, namely the gas-operated heat pump based on absorption or gas motor technology. These, too, normally reach a flow temperature of between 70° and 90° C. Most of these products are in output categories 30 to 100 kW_{th}, which is very important both for new buildings and for renovations (small apartment houses, cf. [8]). The technical utilisation potential for heat pumps will therefore increase sharply from 2006-2008.

According to [1], chapter 6.1, page 28, the energy consumption of fossil fuels for room heating and production of hot water in residential and commercial buildings is 223.670 + 67.413 = 291.083 PJ p.a. According to [19], page 27 and [20], page 16, the consumption of useful heat for room heating and hot water is 198.8 PJ p.a. for households and 65.0 PJ p.a. for the services and agriculture sectors, i.e. a total of 263.8 PJ p.a.

We have assumed that 80% of this is consumed for heating and hot water (i.e. maximum 80° C, no steam production, no process heat) and thus reached figures of 233 PJ p.a. and 211 PJ p.a. respectively. These appear plausible: the estimate cited in [3] for room heating is 222 PJ p.a.

We can therefore conclude that the potential of heat pumps with respect to useful heat (heating and hot water) is 220 PJ p.a.

2.3. Market potential

The term "market potential" refers to the portion of the technical potential that is of interest when the current economic conditions are taken into account. Here we have deliberately refrained from drawing up perspectives. We have simply assumed that energy prices will not change significantly, i.e. 100 kg of oil will cost between CHF 50 and 70, and if the proposed "climate cent" and/or CO_2 fee should be introduced, they will not have any noticeable impact on prices.

The heating market is highly predatory: if the industry manufactures, distributes and installs more heat pumps, demand for oil and gas boilers will fall. The maximum potential growth is limited by structural factors such as production capacities. It would be possible to shift the existing capacities for the 40,000 to 50,000 oil and gas boilers that are installed each year to heat pumps very quickly and at negligible cost (based on statistics produced by Procal, the association of boiler manufacturers).

It is therefore assumed that the trend with respect to prices for heat-pump systems in the retrofitting and large-scale systems segments will be similar to that for heat pumps for new buildings (output below 50kW$_{th}$) over the past few years. The cost reductions that go hand in hand with the increase in unit quantities will continue in the future in the same way as in the period from 1993 to 2005, and will therefore pave the way for the exploitation of new market segments.

It is to be assumed that the technical progress in accordance with chapter 6, "Seasonal Performance Factor",(SPF) will open up opportunities for exploiting additional market segments.

How great is the market potential? We can find an answer to this question in the statistics concerning heat pumps: the market share of heat pumps in new buildings (with thermal output below 20 kW) has risen from 20% in 1992 to 61% in 2004, and in some regions it is now as high as 80%. Providing that technological development and the market trend proceed at a similar pace, we can assume that the market potential is around 75% of the technical potential, or 165 PJ p.a.

2.4. Realisable potential

The term "realisable potential" refers to the portion of the market potential that will be effectively realised in the foreseeable future.

Since there are many parameters and assumptions, it is difficult to make an accurate assessment. We have adopted the figures from the "road maps" of the Federal Energy Research Commission (CORE) [10].

All figures in PJ p.a.	2010	2025	2050 [10]	2050 Sep 05
Useful heat from heat pumps for room heating	8.88	36.06	77.15	51.90
Useful heat from heat pumps for production of hot water	5.57	9.27	12.75	10.70
Total useful heat	14.45	45.33	89.90	62.60

Table 3: Potential of useful heat from Ambiant heat according to the Federal Energy Research Commission (CORE)

There are two options for the year 2050. During the discussions about the realization of the potential, the CORE shifted the figures between the concerned technologies. This does not reduce the potential.

In order to present the above figures more concretely, in chapter 10.1 we have extrapolated the number of heat pumps expected to be in operation by 2050. For this purpose we adopted the calculation model from [2], "Heat pump statistics". This calls for assumptions regarding mean system capacity, running time per year and seasonal performance factor. We adopted findings from previous statistics in order to estimate annual growth. We also assumed that the maximum annual number of heat pumps will not exceed 80% of the overall annual heating market.

Based on our assumptions, the potential for useful heat from heat pumps is approximately 90 PJ p.a.

The realisable potential for useful heat of 90 PJ p.a. corresponds to between 400,000 and 500,000 systems.

2.5. Provision of power supply for the realisable potential

To exploit the realisable useful heat potential of 90 PJ p.a., an electricity supply of between 18 and 22 PJ p.a. would be required, depending on timeframe or mean efficiency of the heat pumps (seasonal performance factor). To calculate on the cautious side, we assumed a mean seasonal performance load of 4.0 – which is equivalent to 22 PJ p.a. power supply and 68 PJ p.a. Ambiant heat. The resulting number of units is shown in chapter 10.1.

For the provision of the required power supply we examined two contrasting options.

a) Without the construction of new electricity production plants

It is possible to provide electricity by implementing measures aimed at increasing efficiency in the heating sector, and thus to avoid having to construct new production plants. This strategy is described in detail in [13]. The two main measures are as follows:

- Replacement of electric resistance heaters by heat pumps (figures, cf. [11])
- Substitution of oil and gas boilers with combined heat and power plants with output levels below 1,000 kW_{el} each (figures, cf. [12]). Assumptions: electrical efficiency = 35%, thermal efficiency = 50%, line losses = 2.5%, and compliance with the more stringent 1992 Clean Air Ordinance (in view of NOx levels).

For the first measure it is necessary to estimate the realisable potential. Technically speaking, any electric heating system can be replaced by a heat pump, but this is certainly not the case from an economic point of view. We shall therefore assume that half the substitution potential is realisable. According to [24], this roughly corresponds to the proportion of storage heating systems to overall heating systems.

For combined heat and power plants, it is the realisable potential that is referred to. The technical potential would in fact be almost three times greater. For the purpose of examining the strict potential, the question of integration of combined heat and power plants into the existing electricity network – especially with many decentral systems – was not taken into account.

	2050		2010	
	Released volume of electricity (GWh p.a.)	Released volume of electricity (PJ p.a.)	Released volume of electricity (GWh p.a.)	Released volume of electricity (PJ p.a.)
Substitution of electric heating systems	1,500	5.4	500	1.8
Replacement of boilers by combined heat and power plants	13,000	46.8	2,500	9.0
TOTAL released volume of electricity	*14,500*	*52.2*	*3,000*	*10.8*
Power requirement of heat pumps	*6,100*	*22.0*	*1,276*	*4.6*
BALANCE (minus = electricity surplus)	**-8,400**	**- 39.6**	**- 1,724**	**- 6.2**

Table 4: Released volume of electricity for powering heat pumps from the substitution of existing electric heating systems and from the substitution of existing boilers by combined heat and power plants, electricity requirements of heat pumps and balance (figures taken from [12] and [11]).

More than enough electricity can be released in order to exploit the estimated useful heat potential by means of heat pumps (cf. 3.4) without having to construct new production facilities.

Figures resulting from the desired useful heat of 90 PJ p.a. cited above:

- 80,000 heat pumps replace 80,000 electric heating systems. Instead of 5.4 PJ p.a. of electricity they only require 1.4 PJ p.a. 4.0 PJ p.a. are freed up and can be used to operate additional heat pumps. They generate 5 PJ p.a. useful heat (concerns systems with lower output);

- 90,000 heat pumps replace boilers – they generate 16 PJ p.a. useful heat from the above 4.0 PJ p.a. of released electricity;

Heat pumps and combined heat and power plants still have to produce 90 minus 21 = 69 PJ p.a. useful heat (net).

- 220,000 heat pumps replace boilers and generate 49 PJ p.a. useful heat and require a power supply of 12 PJ p.a.;

- 90,000 combined heat and power plants replace boilers and generate 12 PJ p.a. electricity and 20 PJ p.a. useful heat from 36 PJ p.a. combustibles.

A total of 390,000 heat pumps would therefore be required. The graph below (Fig. 6) shows the resulting changes in the distribution of the heating systems.

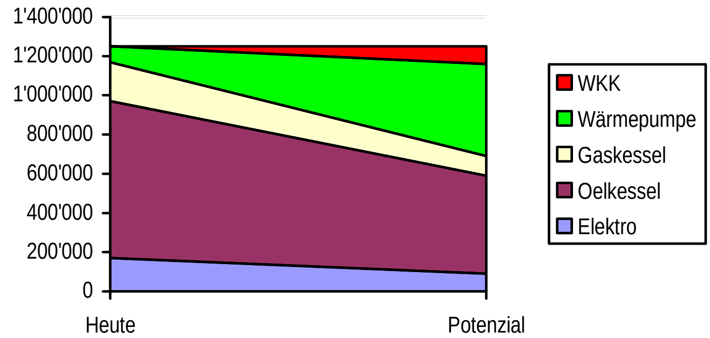

Figure 6: Distribution of heating systems in Switzerland in 2005, versus potential if heat pumps and combined heat and power systems were to replace electric heating systems and boilers.

b) With the construction of new electricity production plants

The new production facilities referred to here concern co-generation plants, many of which are operated with gas and combine a gas turbine with a waste-heat boiler and a steam turbine. The heat is barely utilised or not used at all. With respect to available sizes, they usually take the form of centralised large-scale plants with an electricity output ranging from 5 to 400 MW. The two measures are as follows:

- Replacement of electric resistance heaters by heat pumps (figures, cf. [11]);

- Integration of co-generation systems without heat utilisation, with electrical efficiency of 58% and line losses of 7.5%.

It should be noted here that for both technical and economic reasons, co-generation systems run approximately 3 times longer per year than heat pumps (on average, 5,000 versus 1,700 hours).

- 80,000 heat pumps replace 80,000 electric heating systems. Instead of 5.4 PJ p.a. of electricity they only require 1.4 PJ p.a. 4.0 PJ p.a. are freed up and can be used to operate additional heat pumps. They generate 5 PJ p.a. useful heat (concerns systems with lower output);

- 90,000 heat pumps replace boilers – they generate 16 PJ p.a. useful heat from the above 4.0 PJ p.a. of released electricity.

Heat pumps and co-generation plants have to produce 90 minus 21 = 69 PJ p.a. useful heat (net).

- 310,000 heat pumps replace boilers (mostly oil-fired), and generate 69 PJ p.a. useful heat;

- 1 co-generation plant without heat utilisation and with an output of approximately 300 MW_{el} consumes 33 PJ p.a. in fuel and generates 18 PJ p.a. power supply for the heat pumps.

A total of 480,000 heat pumps would therefore be required. The graph below (Fig. 7) shows the resulting changes in the distribution of the heating systems.

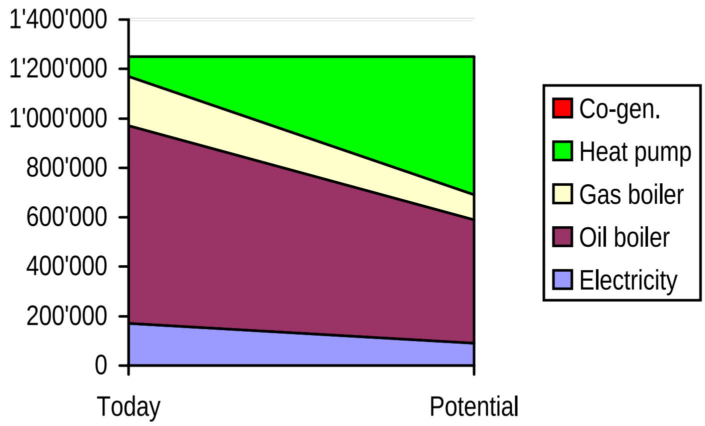

Figure 7: Distribution of heating systems in Switzerland in 2005, versus potential if heat pumps with power supply from co-generation plants were to replace electric heating systems and boilers.

It would of course also be possible to combine options from a) and b).

3. Potential of maximum reduction of CO_2 emissions

In Switzerland, energy for room heating and hot water production is primarily produced with the aid of boilers.

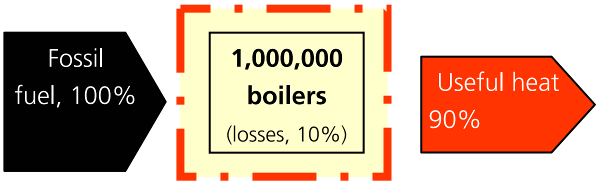

Figure 8: Energy flow of fossil-fuelled boilers

This technology is well developed and is reaching its physical limits. The system limit is determined by the energy production system, including all auxiliary drives, viewed throughout an entire year of operation. It is not possible to reduce CO_2 emissions by a further 10%.

By operating heat pumps together with combined heat and power or co-generation systems (e.g. co-generation with gas and steam turbine without utilisation of heat) it is possible to utilise the combustible much more efficiently.

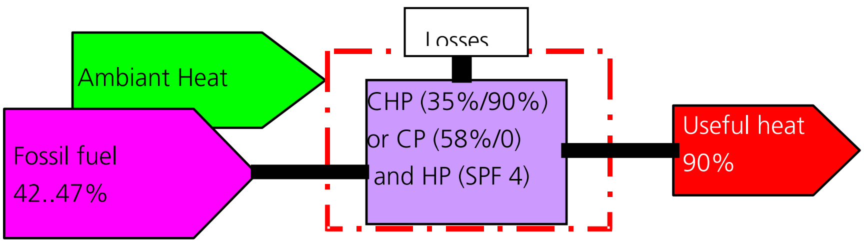

Figure 9: Energy flow for the combination of heat pumps with co-generation plants: the entire power supply drives the heat pump(s).

In this way, fossil fuel consumption – and the corresponding level of CO_2 emissions – can be more than halved: they are in fact reduced by a factor of 2.1 to 2.4.

The best results are achieved from the combination with co-generation plants, thanks to the higher level of electrical efficiency. Furthermore, this solution produces significantly lower levels of NOx emissions than decentralised combined heat and power, which is primarily motor-based.

For the timeframe covered by this study we have taken the figures from [9], which presents analyses of life cycles based on data published by Ecovent in 2000. This means that all grey energies have been taken into account, especially the CO_2 equivalent from refrigerant losses through heat pumps.

Our technical assumptions were as follows: on average, heat pumps operate at an seasonal performance factor of 4.0, and the average efficiency of combined heat and power plants is $35\%_{el}$ and $55\%_{th}$. Modern boilers generate between 260 g (CO_2 equivalent) per kWh (gas, condensing) and 350 g (CO_2 equivalent) per kWh (oil) ([9], page 10). The distribution of boilers as of 2000 was 814,827 oil-fired and 200,187 gas-fired (from [8]). The mean level of emissions was 330 g (CO_2 equivalent) per kWh. The various calculated figures have been rounded up or down for the sake of convenience. A prerequisite for combined heat and power systems is that they meet the more stringent requirements of the 1992 Clean-Air Ordinance, and not the less stringent requirements of the 1998 Clean-Air Ordinance, governing NOx emissions. Please refer to Chapter 10.4 for more detailed calculations.

For the provision of the power supply for heat pumps, the Swiss Federal Office of Energy's strategy is described in [13]. There are three potential scenarios:

- The power supply can be released through the substitution of electrical resistance heaters with heat pumps, and by replacing existing boilers with combined heat and power systems. In the case of substitution of electrical resistance heaters with heat pumps, the released electricity does not produce any additional CO_2 emissions. Regardless of how this power supply is produced, for every substituted electrical resistance heater sufficient electricity is freed up for 3 additional heat pumps. In order to calculate the specific reduction, the emissions from replaced boilers should be distributed over the total quantity of useful heat (boiler + electric heating). We thus obtain a reduction of specific emissions of (seasonal performance factor –1) / seasonal performance factor = 0.75. The CO_2 reduction amounts to 240 g (CO_2 equivalent) per kWh.

- With electricity from efficient wood-fired power plants at full heat utilisation, approximately 150 g (CO_2 equivalent) / kWh ([9], page 11) are generated. The CO_2 reduction then amounts to 170 g (CO_2 equivalent) per kWh.

- The power supply is produced in new, advanced co-generation plants. Gas-turbine and steam-turbine power plants play a significant role. The CO_2 reduction results from the difference between the CO_2 emissions if the useful heat were to be produced from boilers with fossil fuels instead of by heat pumps, and those emissions attributable to electricity generation from fossil fuels, assuming that the heat produced in the power plant cannot be utilised at all. With electricity from co-generation plants, heat pumps would emit approximately 125 g (CO_2 equivalent) / kWh ([9], page 11). The CO_2 reduction thus amounts to 195 g (CO_2 equivalent) per kWh.

The CO_2 reduction amounts to between 170 and 240 g (CO_2 equivalent) /kWh, depending on the composition of the power supply for heat pumps. To calculate an approximate figure, we shall take a mean level of 200 g (CO_2 equivalent) / kWh.

Assuming a utilisable potential of 90 PJ p.a. we obtain the following figures:

Potentials	Energy from the environment	Useful heat	CO_2 reduction in tonnes or in % of emissions due to combustibles
2010	2’724GWh p.a.	4’000GWh p.a.	800,000 tonnes or 3%
2050	68 PJ p.a. or 19,000 GWh p.a.	90 PJ p.a. or 25,000 GWh p.a.	5,000,000 tonnes or 21%

Table 5: Utilisable potentials for reduction of CO_2 emissions from combustibles with heat pumps and power supply from combination of substituted electric heating systems, combined heat and power and co-generation plants.
The total volume of emissions is 40.8 million tonnes, 24.3 million of which come from combustibles, according to the CO_2 inventory of the Swiss Agency for the Environment, Forests and Landscape (SAEFL) [1].

The potential of reductions of CO_2 emissions amounts to 5 million tonnes, or 21% of the emissions from boilers.

4. Potentials of electricity production from fossil fuels with 0 to 10% reduction of CO_2.

According to 4 (above), there is potential to halve the level of CO_2 emissions. One way of looking at it is that part of or all eliminated CO_2 emissions from boilers could be used (or effectively “sacrificed”) for electricity production from fossil fuels. This possibility has already been formulated in [17]. Two examples are analysed below:

- 10% CO_2 reduction permits the production of 21 to 26 PJ p.a. of electricity from fossil fuels;

- Zero CO_2 reduction permits the production of 25 to 31 PJ p.a. of electricity from fossil fuels.

To illustrate this, we can use the figures cited in Chapter 3.4: The goal is to produce 90 PJ p.a. useful heat with a maximum of 72 PJ p.a. from Ambiant heat.

Our technical assumptions are as follows: On average, heat pumps operate at an seasonal performance factor of 4.0, the average efficiency of combined heat and power plants is

35%$_{el}$ and 55%$_{th}$, gas co-generation plants achieve an efficiency of 58%; line losses amount to 2.5% (combined heat and power) and 7.5% (co-generation).

Once again, the various figures have been rounded up or down for the sake of convenience. As before, a prerequisite for combined heat and power systems is that they meet the more stringent requirements of the 1992 Clean-Air Ordinance, and not the less stringent requirements of the 1998 Clean-Air Ordinance, governing NOx emissions. Please refer to Chapter 10.4 for more detailed calculations.

4.1. Potential of electricity production from fossil fuels with 10% reduction of CO_2 emissions

The combination of heat pumps with combined heat and power systems permits generation of electricity from fossil fuels while simultaneously reducing the volume of CO_2 emissions. Between 21 and 26% of electricity can be produced with a 10% reduction in pollutants.

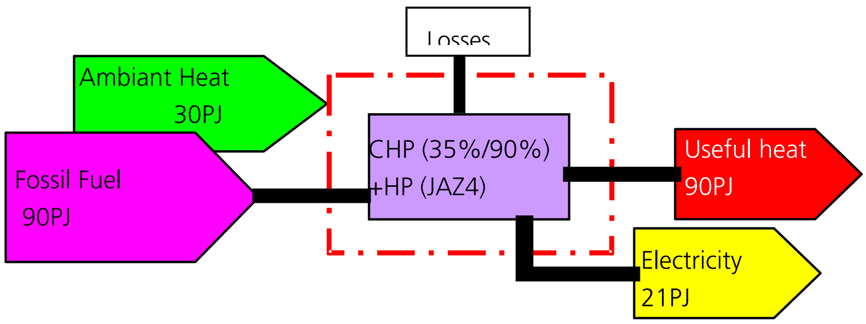

Figure 10: Energy flow for the combination of heat pumps with combined heat and power systems; 33% of the power supply drives the heat pump(s).

Due to the generation of heat by combined heat and power plants, the heat to be produced by co-generation is reduced, as is the utilisation of Ambiant heat.

With the use of co-generation plants, slightly more electricity is produced even without utilising their heat. The volume of pollutants (especially NOx) is also lower.

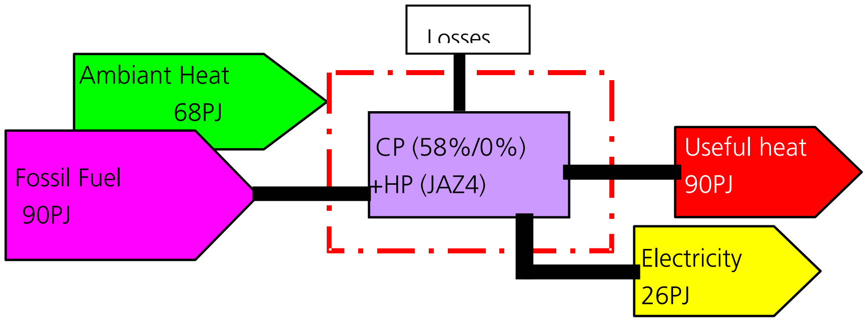

Figure 11: Energy flow for the combination of heat pumps with co-generation plants; 47% of the power supply drives the heat pump(s).

With a 10% reduction in fossil fuels versus the present-day level, it is possible to produce between 21 and 26 PJ p.a., or 5.8 to 7.2 TWh p.a. of electricity. This is equivalent to between 10 and 13% of Switzerland's electricity consumption in 2004.

4.2. Potential of electricity production from fossil fuels with unchanged CO_2 emissions

The combination of heat pumps with combined heat and power systems permits generation of electricity from fossil fuels while the volume of CO_2 emissions remains unchanged. Using the same quantity of combustibles and the same quantity of useful heat as with boilers, it is possible to produce 25 to 31% of electricity from fossil fuels without CO_2 emissions.

To illustrate this, we can use the figures cited in Chapter 3.4: Here, too, the goal is to produce 90 PJ p.a. useful heat with a maximum of 72 PJ p.a. from Ambiant heat using 90 PJ p.a. of combustibles. Electricity production is maximised.

Assumptions: Our technical prerequisites are that on average, heat pumps operate at an seasonal performance factor of 4.0, the average efficiency of combined heat and power plants is $35\%_{el}$ and $55\%_{th}$, gas co-generation plants achieve an efficiency of 58%; line losses amount to 2.5% (combined heat and power) and 7.5% (co-generation).

Once again, the various calculated figures have been rounded up or down for the sake of convenience. As before, a prerequisite for combined heat and power systems is that they meet the more stringent requirements of Article 92 of the Clean-Air Ordinance, and not the less stringent requirements of Article 98 of the Clean-Air Ordinance. Please refer to Chapter 10.4 for more detailed calculations.

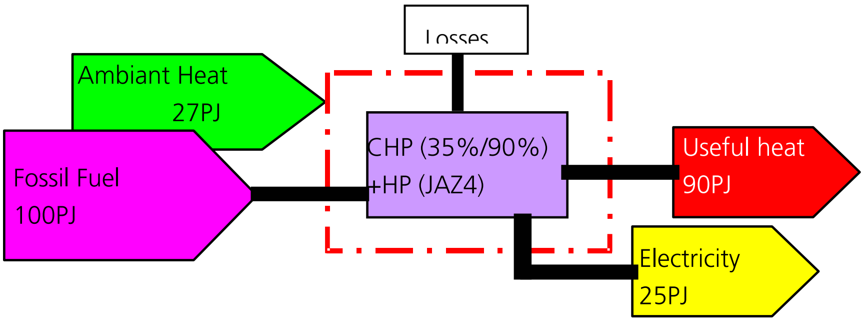

Figure 12: Energy flow for the combination of heat pumps with combined heat and power systems; 33% of the power supply drives the heat pump(s).

Due to the generation of heat by combined heat and power plants, the heat to be produced by co-generation is reduced, as is the utilisation of Ambiant heat.

With the use of co-generation plants, slightly more electricity is produced even without utilising their heat:

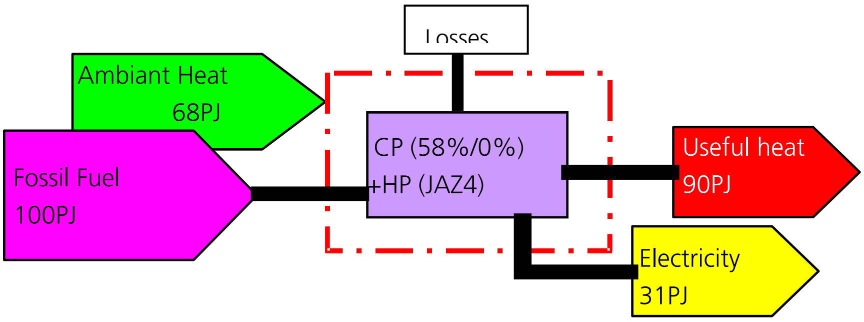

Figure 13: Energy flow for the combination of heat pumps with co-generation plants; 47% of the power supply drives the heat pump(s).

With the same quantity of fossil fuels as today, it is possible to produce between 25 and 31 PJ p.a., or 6.9 to 8.6 TWh p.a. of electricity. This is equivalent to between 12 and 15% of Switzerland’s electricity consumption in 2004.

5. Comments/explanations regarding our assumptions

- Service life of heat pumps

  According to existing statistics, the assumed service life of heat pumps is 15 years. This corresponds to the service life in accordance with the SIA (Swiss Association of Engineers and Architects), which is also assumed by banks for mortgage and amortisation calculations. Based on practical findings within the industry, as well as on analyses of heat pump systems used by the Swiss Federal Office of Energy, the real service life of new systems is closer to 20 years than to 15. On average, systems already in use can be expected to reach a service life of 15 years without difficulty. As time goes by, this figure will increase so that by 2020 we can anticipate an average service life of 20 years for all systems, while this can reasonably be expected to increase to between 25 and 30 years by 2050.

- Operating time

  As of the end of 2003, the mean operating time of heat pumps was 1,682 hours p.a. Method of calculation: produced heat divided by heating capacity. These figures thus concern annual full loads. In future, two trends are likely to have an impact on operating time. On the one hand, heating periods will become shorter thanks to improved heat insulation in buildings. And on the other hand, operating times will increase because heat pump systems will also increasingly be used for the production of hot water. The latter applies especially in that the greatest market potential for heat pumps in the future lies in the renovation of existing (and in particular oil-fired) heating systems. These two trends are likely to more or less offset one another, so that the mean annual number of hours of full-load operation can be expected to stabilise at around 1,700 hours.

- Average capacity

  As of the end of 2003, the mean heating capacity of all heat pumps was around 16kW_{th}. In terms of size, the majority of systems in use have a heating capacity of less than 20 kW, but a handful of large-scale systems quickly change the overall picture: mathematically, a 500 kW system is equivalent to 100 small heat pumps in buildings constructed in accordance with "Minergie" criteria!
  In 1980, the mean heating capacity of all heat pumps was 24 kW_{th}. A comparison of distribution in 1980 versus 2003 shows that the situation has changed considerably:

Year	< 20 kW	20-50 kW	50-100 kW	>100 kW
1980	2,531	398	128	183
2003	8,130	416	90	41

Table 6: Distribution by capacity – comparison between 1980 and 2003.

In 1980 it was primarily medium-sized to large-scale systems that were installed, and this is likely to be the case again in the future.

The greatest market potentials are to be found in the following two segments: Renovation of heating systems (tendency towards higher heating capacities than in new buildings of the same type) and installations of larger systems. The improvement of heat insulation in buildings, which reduces the required mean heating capacity, represents a tendency in the opposite direction. It is therefore difficult to estimate a precise figure.

Based on the consumption data presented in [8], in Chapter 8 of this study we have projected a mean capacity of existing boiler heating systems of approximately 35 kW_{th} (this concerns the mean heating capacity, not the mean capacity of the boilers). Our estimate of a mean heating capacity for heat pumps as of 2030 is 25kW_{th}, which is certainly realistic.

- Costs

The "Technology monitoring" project implemented by the Swiss Federal Office of Energy [16] has supplied reliable data. In 2003, a heat pump cost around CHF 1,600 per kW_{th} (air/water heat pump, heat production only, without hydronic distribution). The costs have fallen by almost half within 10 years, and a further halving can be realised through scaling effects.

Reasoning: heat pump manufacturers buy components and assemble them. The components are made by global manufacturing companies such as Copeland, Danfos, etc., who only produce them if the market for heat pumps is big enough. The situation was underscored by renowned compressor manufacturer Copeland, who introduced a new series of compressors for use in heat pumps in 2004, with the consequence that component prices fell sharply. However, the minimum quantities are very high: for such companies, 10,000 units are merely pilot production … and a genuine market segment starts from 50,000 p.a. If the heat pumps market becomes big enough in Europe, the modified components will be available at very low prices, and manufacturers of heat pumps will then be able to produce more machines by means of automation. Such investments are worthwhile from 30,000 to 50,000 units p.a. (cf. final report of SFOE project, "Swiss Retrofit Heat Pump SRHP").

- Market shares, market situation

The potential for the quantity of heat pumps is plausible, since the signs are that heat pumps will start replacing boilers.

In 2003, 42,939 heating systems were installed in Switzerland – 32,460 with boilers and 8,732 with heat pumps. We therefore assume that the heating market will require a constant quantity of around 50,000 systems p.a.

- Seasonal performance factor

The mean seasonal performance factor of systems throughout Switzerland is currently close to 3.0 (this figure was calculated in [5]). For systems installed today in new buildings, the mean seasonal performance factor is slightly higher (around 3.5). In its concept for the period from 2004 to 2007 for Ambiant heat, the Federal Energy Research Commission (CORE) approved the following seasonal performance factors (extract):

	Main system	Components	Implementation	Infrastructure	Background conditions
2004-07	SPF in field: A/W=3.0 (renovation: 2.7) S/W=4.0 (renovation: 3.0) W/W=4.5 (renovation: 3.3) Combined refrigeration/heat generation)	Environmental tools (NH_3, CO_2) with same SPF Geothermal sensors with CO2 (direct evaporation)	<50 kW: focus on retrofitting, esp. of existing electric resistance heaters >50 kW: Combined use of heat and refrigeration with 25% higher overall degree of efficiency Optimisation of commercial cooling systems	Increased use of heat pumps in house renovations	Liberalisation of electriicity market (+) Price (-) Acceptance would be even greater with higher oil/gas price (e.g. Sweden)
2008-19	Exergy optimisation -> 80% -> max. SPF achieved by 2015 in field, i.e. A/W= 5 S/W= 6 W/W= 8	New compressors Combination heat pump / winter heat	Optimum structural integration of heat pumps Use of exhaust air as source of heat 20% market share for heating renovations, incl. replacement of first heat pumps	Efficient CHP plants generate electricity for decentralised heart pumps, i.e. approx. 20 g&d approx. 5,000 SwissMotor and approx. 10,000 small fuel cells Worldwide concentration of manufacturers, only 2 in Switzerland	CO_2 fee? Oil and gas heating systems prohibited
2020-29	WW output / heating output 1:1	Seasonal storage systems / heat pumps / solar heat	R&D programme mainly financed by industry Wave of demolitions of old buildings	Biofuels in hydropower plants	Oil price > 50$ per barrel (+)
Nach 2030	In-built micro heat pumps with direct evaporation and direct condensation	Oil-free compressors, environment-friendly coolants with NH3 and CO2	R&D solely financed by industry Only NH3 and CO2 permitted	Electricity from hydropower and CHP	Oil no longer used for heating purposes, heat pumps are normall

Table 7: Objectives attained to date and specified targets. Extract from concept for the period from 2004 to 2007 for Ambiant heat, combined heat and power plants, refrigeration, approved by THE FEDERAL ENERGY RESEARCH COMMISSION (CORE) on 10.9.2004 (format has been modified, but content is unchanged).
Abbreviations: A = air / S = solar / W = water

For the purpose of estimating potentials, a mean seasonal performance factor of 4.0 may be assumed for all systems and up to 2020. New, more efficient systems will raise the average factor, but the quantity of new installations is always lower than the number of existing ones, hence the apparently slow improvement in the average factor for all installed systems. Over the longer term (up to 2050) we can safely assume a factor of 5.0.

- Electricity consumption data

The majority of heat pumps in use will be those powered by electricity, and recent trends have also moved in this direction, for example heat pumps with magnetocaloric effect. Here we would like to recall some electricity consumption data (from [2], [12], [14] and [18]:

	TWh p.a.	In % of 2003 consumption
Consumption of all heat pumps, 2000	0.61	1.1
Consumption of all heat pumps, 2003	0.69	1.2
Consumption of all heat pumps, 2004	0.70	1.2
Potential consumption of all heat pumps, 2010	1.22	2.2
Potential consumption of all heat pumps, 2050	5.0	10.0
Consumption of electric heating systems	3.0	5.5
Consumption of oil and gas burners	0.6	1.1
Consumption of cooling systems (air conditioners, refrigeration systems…)	5.5	9.1
Consumption of household appliances	7.1	12.9
Refrigerators and freezers	2.5	4.5
Dishwashers	0.4	0.7
Washing machines	0.6	1.1
Clothes dryers	0.4	0.7
Coffee machines	0.4	0.7
Lighting	5.8	10.5
Consumption for office, communication	1.5	2.7
Consumer electronics	1.2	2.2

Table 8: Electricity consumption of selected types of equipment, according to [2] and [18].

Heat pumps require relatively little electricity: as of the end of 2003, their consumption was roughly the same as that for washing machines. By the end of 2050, heat pumps will account for approximately two-thirds of the consumption of all household appliances if the potentials are fully utilised. The increase for new heat pumps can largely be attributed to the substitution of electric heating systems. Over the long term, it should be possible for the efficiency of household appliances and refrigeration equipment to be increased by an average of 25%.

6. References

[1] Programmziele EnergieSchweiz, Sektorziele und Zielbeiträge 2001 und 2002, BFE, Bern, Februar 2004 (*SwissEnergy objectives, sector objectives and contributions towards objectives, SFOE, Bern, February 2004*)
SwissEnergy data according to [1], Chapt. 6.1, p. 28, Chapt. 3.4, p. 12 and Chapt. 3.3, p. 11:
Combined consumption of fossil fuels for heating and hot water in residential dwellings and office buildings, 223,670 + 67,413 = 291,083 TJ
SwissEnergy target for combustibles, total: 50,503 TJ
SwissEnergy target for combustibles, required contribution towards target from renewable energy: 10,800 TJ

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[12] Ueberprüfung der Erehebung der Widerstandsheizungen, BFE, Sektion Statistik, Notiz vom 8.9.2003 (*Review of survey of resistance heaters, SFOE, Statistics section, memo dated 8 September 2003*)

[13] Die Wärme-Kraft-Kopplung im Programm EnergieSchweiz, BFE, August 2003 (Dok.-ID 003692950) (*Combined heat and power in the SwissEnergy programme, SFOE, August 2003 – reference 003692950*)

[14] J. Nipkow, Stand-by-Verbrauch von Haushaltgeräten, BFE, Bern, Juni 2003 (*Stand-by consumption of household appliances, SFOE, Bern, June 2003*)

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7. List of abbreviations

p.a.	Per annum
CORE	Federal Energy Research Commission
CHP	Coupled heat and power (all the heat is used because heat-driven)
CP	Power plant with combined cycle turbines (the heat is NOT used)
G	gram
GWh	Gigawatt hours
KW	Kilowatt
HP	Heat pump
PJ	Petajoule
TWh	Terawatt hours
SPF	Seasonal performance factor

8. List of illustrations and tables

9. Detailed data

9.1. Estimate of number of systems by 2050

Input fields for extrapolation		12.09.2005	
Calculated fields		BFE/EE/F. Rognon	

Figures from furnaces statistics from 2000 for comparison				
Oil furnaces	Sales p.a.	Sales in retrofit	Replacement rate on cumulated stock	Replacement rate on annual sales
814'827	21'200	18'020	2.2%	85.0%

Parameters for calculations:

Annual growth versus prior year is 10% during SwissEnergy and decreases after 2010
Annual sales do not go over 40'000 units p.a. that means max. market share of 80%
No. of accumulated systems may not exceed 80% of all boiler systems, i.e. max. 812'011
No. of non-accumulated heat pumps as % of annual sale increases to 4% (that means mean lifetime of 25 years)
Replacement of heat pump by heat pump increases up to 100% (market saturation)
Average capacity increases up to 25kW until 2030

		PJ	TJ
Heat from furnaces	(oil & gas)	222	222'000
Running time	hours	1'700	
Output	GW	36	
Output	MW	36'275	
No. Of	oil, gas, coal, electric	1'015'014	
Average capacity	kW	35.7	

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Steps toward a sustainable development, Novatlantis, CEPE ETH, Zurich, mars 2004
According to 2004 population census, cf. www.bfs.admin.ch/bfs/portal/de/index/themen/bau-_und_wohnungswese

Capacities and energy calculated on volume basis

Year	No. of systems (accumulated)	Growth in % versus prior year	Growth in no. Of cumulated heat pumps	Annual heat pump sale (total)	No. of non-accumulated heat pumps (replaced by heat pumps or others)	No. of non-accumulated heat pumps as % of annual sale	No. of non-accumulated heat pumps as % of all heat pumps
1990	34824						
1991	0						
1992	38268						
1993	39750	3.9					
1994	42446	6.8					
1995	45064	6.2		3309			
1996	47864	6.2	2'800	4160	691	16.6%	1.5%
1997	50988	6.5	3'124	4207	1360	32.3%	2.8%
1998	55209	8.3	4'221	5225	1083	20.7%	2.1%
1999	59288	7.4	4'079	6155	1004	16.3%	1.8%
2000	64050	8.0	4'762	6160	2076	33.7%	3.5%
2001	68996	7.7	4'946	6943	1398	20.1%	2.2%
2002	74005	7.3	5'009	7554	1997	26.4%	2.9%
2003	80011	8.1	6'006	8677	2545	29.3%	3.4%
2004	86'950	10.0	6'939	9796	2671	27.3%	3.3%
2005	95'645	10.0	8'695	11'598	2903	25.0%	3.3%
2006	105'210	10.0	9'565	12'757	3193	25.0%	3.3%
2007	115'730	10.0	10'521	14'033	3512	25.0%	3.3%
2008	127'303	10.0	11'573	15'436	3863	25.0%	3.3%
2009	140'034	10.0	12'730	16'980	4250	25.0%	3.3%
2010	154'037	10.0	14'003	18'678	4675	25.0%	3.3%
2011	169'441	10.0	15'404	21'565	6161	28.6%	4.0%
2012	186'385	9.6	16'944	23'722	6778	28.6%	4.0%
2013	204'278	9.2	17'893	25'348	7455	29.4%	4.0%
2014	223'072	8.8	18'794	26'965	8171	30.3%	4.0%
2015	242'702	8.4	19'630	28'553	8923	31.3%	4.0%
2016	263'089	8.0	20'387	30'095	9708	32.3%	4.0%
2017	284'136	7.6	21'047	31'571	10524	33.3%	4.0%
2018	305'730	7.2	21'594	32'960	11365	34.5%	4.0%
2019	327'743	6.8	22'013	34'242	12229	35.7%	4.0%
2020	350'029	6.4	22'287	35'396	13110	37.0%	4.0%
2021	372'431	6.0	22'402	36'403	14001	38.5%	4.0%
2022	394'777	5.6	22'346	37'243	14897	40.0%	4.0%
2023	416'885	5.2	22'108	37'899	15791	41.7%	4.0%
2024	438'563	4.8	21'678	38'353	16675	43.5%	4.0%

Year	No. of systems (accumulated)	Growth in % versus prior year	Growth in no. Of cumulated heat pumps	Annual heat pump sale (total)	No. of non-accumulated heat pumps (replaced by heat pumps or others)	No. of non-accumulated heat pumps as % of annual sale	No. of non-accumulated heat pumps as % of all heat pumps
2025	459'614	4.4	21'051	38'594	17543	45.5%	4.0%
2026	479'837	4.0	20'223	38'608	18385	47.6%	4.0%
2027	499'030	3.6	19'193	38'387	19193	50.0%	4.0%
2028	516'995	3.2	17'965	37'926	19961	52.6%	4.0%
2029	533'539	2.8	16'544	37'224	20680	55.6%	4.0%
2030	548'478	2.4	14'939	36'281	21342	58.8%	4.0%
2031	561'642	2.0	13'163	35'103	21939	62.5%	4.0%
2032	572'874	1.6	11'233	33'698	22466	66.7%	4.0%
2033	582'040	1.2	9'166	32'081	22915	71.4%	4.0%
2034	589'025	0.8	6'984	30'266	23282	76.9%	4.0%
2035	593'737	0.4	4'712	28'273	23561	83.3%	4.0%
2036	596'112	0.0	2'375	26'124	23749	90.9%	4.0%
2037	596'112	0.0	0	23'844	23844	100.0%	4.0%
2038	596'112	0.0	0	23'844	23844	100.0%	4.0%
2039	596'112	0.0	0	23'844	23844	100.0%	4.0%
2040	596'112	0.0	0	23'844	23844	100.0%	4.0%
2041	596'112	0.0	0	23'844	23844	100.0%	4.0%
2042	596'112	0.0	0	23'844	23844	100.0%	4.0%
2043	596'112	0.0	0	23'844	23844	100.0%	4.0%
2044	596'112	0.0	0	23'844	23844	100.0%	4.0%
2045	596'112	0.0	0	23'844	23844	100.0%	4.0%
2046	596'112	0.0	0	23'844	23844	100.0%	4.0%
2047	596'112	0.0	0	23'844	23844	100.0%	4.0%
2048	596'112	0.0	0	23'844	23844	100.0%	4.0%
2049	596'112	0.0	0	23'844	23844	100.0%	4.0%
2050	596'112	0.0	0	23'844	23844	100.0%	4.0%

Year	Thermal output power installed / no. of installations (kW/unit)	Installed output power (MW)	Seasonal performance factor (SPF)	Electricity consumption (GWh)	Heat production (GWh)	Heat production (TJ)	Part of renewabel energy (TJ)
1990	24	850	2.6	534	**4'975**	3'053	39'685
1991					**0**	0	
1992	24	902	2.6	591	**5'555**	3'427	40'321
1993	23	921	2.6	605	**5'731**	3'553	40'050
1994	23	956	2.7	574	**5'533**	3'467	36'211
1995	22	979	2.7	629	**6'084**	3'820	37'502
1996	21	1003	2.7	688	**6'653**	4'176	38'609
1997	20	1030	2.8	630	**6'239**	3'971	33'988
1998	19	1074	2.8	662	**6'631**	4'248	33'364
1999	19	1103	2.8	663	**6'761**	4'374	31'676
2000	18	1136	2.9	638	**6'620**	4'324	28'712
2001	17	1175	2.9	673	**7'056**	4'633	28'407
2002	16	1216	3.0	665	**7'106**	4'712	26'674
2003	16	1268	3.0	711	**7'679**	5'119	26'659
2004	16	1'391	3.1	763	**8'514**	5'768	27'200
2005	16	1'559	3.2	841	**9'541**	6'512	27'710
2006	16	1'683	3.2	894	**10'302**	7'083	27'200
2007	17	1'967	3.3	1'029	**12'041**	8'336	28'900
2008	17	2'164	3.3	1'115	**13'245**	9'231	28'900
2009	17	2'381	3.4	1'208	**14'569**	10'220	28'900
2010	17	2'619	3.4	1'309	**16'026**	11'312	28'900
2011	18	3'050	3.5	1'503	**18'666**	13'255	30'600
2012	18	3'355	3.5	1'630	**20'532**	14'666	30'600
2013	18	3'677	3.6	1'761	**22'503**	16'164	30'600
2014	18	4'015	3.6	1'896	**24'574**	17'748	30'600
2015	19	4'611	3.7	2'148	**28'221**	20'489	32'300
2016	19	4'999	3.7	2'297	**30'592**	22'324	32'300
2017	19	5'399	3.8	2'447	**33'039**	24'229	32'300
2018	19	5'809	3.8	2'599	**35'550**	26'195	32'300
2019	20	6'555	3.9	2'894	**40'116**	29'696	34'000
2020	20	7'001	4.0	2'975	**42'844**	32'133	34'000
2021	21	7'821	4.0	3'297	**47'865**	35'997	35'700
2022	21	8'290	4.1	3'466	**50'737**	38'260	35'700
2023	22	9'171	4.1	3'803	**56'129**	42'439	37'400
2024	22	9'648	4.1	3'968	**59'048**	44'762	37'400

Year	Thermal output power installed / no. of installations (kW/unit)	Installed output power (MW)	Seasonal performance factor (SPF)	Electricity consumption (GWh)	Heat production (GWh)	Heat production (TJ)	Part of renewabel energy (TJ)
2025	23	10'571	4.2	4'313	**64'695**	49'168	39'100
2026	23	11'036	4.2	4'467	**67'542**	51'460	39'100
2027	24	11'977	4.2	4'810	**73'298**	55'982	40'800
2028	24	12'408	4.3	4'944	**75'936**	58'138	40'800
2029	24	12'805	4.3	5'063	**78'366**	60'140	40'800
2030	25	13'712	4.3	5'380	**83'917**	64'550	42'500
2031	25	14'041	4.4	5'467	**85'931**	66'251	42'500
2032	25	14'322	4.4	5'534	**87'650**	67'728	42'500
2033	25	14'551	4.4	5'580	**89'052**	68'963	42'500
2034	25	14'726	4.5	5'605	**90'121**	69'942	42'500
2035	25	14'843	4.5	5'608	**90'842**	70'652	42'500
2036	25	14'903	4.5	5'589	**91'205**	71'084	42'500
2037	25	14'903	4.6	5'548	**91'205**	71'231	42'500
2038	25	14'903	4.6	5'508	**91'205**	71'375	42'500
2039	25	14'903	4.6	5'469	**91'205**	71'518	42'500
2040	25	14'903	4.7	5'430	**91'205**	71'658	42'500
2041	25	14'903	4.7	5'391	**91'205**	71'797	42'500
2042	25	14'903	4.7	5'353	**91'205**	71'933	42'500
2043	25	14'903	4.8	5'316	**91'205**	72'068	42'500
2044	25	14'903	4.8	5'279	**91'205**	72'201	42'500
2045	25	14'903	4.8	5'243	**91'205**	72'332	42'500
2046	25	14'903	4.9	5'207	**91'205**	72'461	42'500
2047	25	14'903	4.9	5'171	**91'205**	72'588	42'500
2048	25	14'903	4.9	5'136	**91'205**	72'714	42'500
2049	25	14'903	5.0	5'102	**91'205**	72'838	42'500
2050	25	14'903	5.0	5'068	**91'205**	72'960	42'500

9.2. Heating market statistics – 2000 and 2003

Data taken from SFOE renewable energy statistics for 2003 and procal (www.procal.ch/statistik.html)
Note: approx. 80% of boilers replace existing ones

HEATING SYSTEMS		2000	2003	2003
Oil boilers	conventional	21,200	17,000	40%
	condensing	0	950	2%
Gas boilers	all	12,770	14,510	34%
Solid fuel combustion	all	950	860	2%
Heat pumps		7,164	8,732	20%
Wood combustion	Pellets	330	617	1%
	automatic <50 kW	67	136	0%
	automatic >50 kW	258	134	0%
TOTAL		**42,739**	**42,939**	
BOILERS		*2000*	*2003*	
Gas boilers	*all*	*990*	*870*	
Water heaters	*all*	*28,185*	*28,510*	
Flow-through heaters		*2,300*	*2,000*	
Heat pumps	*all*	*244*	*400*	
TOTAL		*31,719*	*31,780*	
TOTAL heating systems and boilers		74,458	74,719	

9.3. Overview of energy sources for heating systems in buildings, based on 2000 national census

Buildings by type of heating system and energy source for heating

Data obtained from: http://www.bfs.admin.ch/bfs/portal/de/index/themen/bau-_und_wohnungswesen/gebaeude_und_wohnungen/blank/kennzahlen0/gebaeude/heizung.html

	Year	1990	1990	2000	2000
		absolute	in percent	absolute	in percent
Energy source for heating		1990		2000	
	Heating oil	756,001	58,7	814,827	56,0
	Wood	221,910	17,2	189,571	13,0
	Heat pump	24,744	1,9	60,109	4,1
	Electricity	155,020	12,0	166,248	11,4
	Gas	110,149	8,6	200,187	13,8
	District heat	14,280	1,1	20,593	1,4
	Coal	5,241	0,4	1,057	0,1
	Solar collectors	375	0,0	944	0,1
	Others	366	0,0	964	0,1
		1,288,086		1,454,500	

9.4. Detailed calculations for Chapter 5 (See also [17])

Calculations for variants heat pumps + CHP and HP + CP, in %
In italics = combustibke and proportion of power for heat pump from CHP/CP
In frame = targets

CHP and HP

Case	*Combu stible*	CHP electricity gross	CHP electricity net	CHP heat	*Proportion of CHP electricity for HP*	Electricity for HP	Heat from HP	Ambiant heat used by HP	Heat (total)	Released electricity
1	*47.0*	16.5	16.0	25.9	*1.000*	16.04	64.2	48.1	90	0.0
2	*36.0*	12.6	12.3	19.8	*1.000*	12.29	49.1	36.9	69	0.0
3	*90.0*	31.5	30.7	49.5	*0.330*	10.14	40.5	30.4	90	20.6
4	*100.0*	35.0	34.1	55.0	*0.260*	8.87	35.5	26.6	90	25.3

Case	In Text	Comments
1	Fig. 2,9	PJ, heat 90 PJ with minimum combustibles, without electricity
2	Kap 3.5a	PJ, CHP+HP produce together 69PJ heat
3	Fig. 10	PJ, heat is maximum 90PJ with lowest electricity and combustible -10%
4	Fig. 12	PJ, with maximum of electricity, combustible as if furnaces (100PJ), maxi 72PJ of ambiant heat

CHP	ETAel	0.35
	ETAth	0.55
Network	losses	0.025
HP	SPF	4

CCT+HP

Case	*Combu stible*	CCT electricity gross	CCT electricity net	Heat CCT	*Proportion of CCT electricity for HP*	Electricity for HP	Heat from HP	Ambiant heat used by HP	Heat (total)	Released electricity
1	*42.0*	24.4	22.5	0.0	*1.000*	22.53	90.1	67.6	90.1	0.0
2	*33.0*	19.1	17.7	0.0	*1.000*	17.70	70.8	53.1	70.8	0.0
3	*100.0*	58.0	53.7	0.0	*0.420*	22.53	90.1	67.6	90.1	31.1
4	*90.0*	52.2	48.3	0.0	*0.466*	22.50	90.0	67.5	90.0	25.8

Case	In text	Comments
1	Fig. 3,9	PJ, heat 90PJ with minimal combustible minimal, without electricity
2	Kap 3.5b	PJ, CCT+HP produce 69PJ of heat
3	Fig. 4,13	PJ, heat 90PJ, combustible as if with furnace (100PJ)
4	Fig. 11	PJ, with heat maximum 90PJ and maximize electricity

CCT	ETAel	0.58
	ETAth	0
Network	losses	0.075
HP	SPF	4

Conversion of PJ in numbers		
Numbers	PJ	PJ/install.
1'015'014	*222*	0.000219
411'492	*90*	
315'477	*69*	
224'035	*49*	
86'871	*19*	
73'154	*16*	