PAST AND FUTURE OF HEAT PUMPS IN THE SWISS ENERGY STRATEGY

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Abstract: In Switzerland, oil and gas still account for more than 67% of total energy consumption, a large part of which is mainly used for room heating and domestic hot water preparation. In 2007 the Swiss Federal Council updated its energy strategy, the main objectives being to reduce overall energy consumption, ensure security of energy supply and increase climate protection by reducing the emissions of greenhouse gases. Consequently, heat pumps (HPs) have been identified as a major asset in achieving some of these objectives. Since the early nineties the Swiss Federal Office of Energy (SFOE) has encouraged the use of heat pumps by implementing a set of tools, including both direct measures (grant programs that cover up to 60% of the extra investment costs) and indirect (information, communication, quality management and education), that have resulted in a total of more than 180,000 HPs being installed in 2010. Based on this achievement, the SFOE has set the objective of having at least 400,000 HP units installed throughout Switzerland by 2020. Consequently, the focus for the next ten years will be on replacing existing fossil-fuel and electric heating systems.

Key Words: heat pump, market, energy, strategy, economics

1 INTRODUCTION

Swiss energy consumption increased by 26% between 1980 and 2009, from 193 TWh to 243 TWh [1]. Oil and gas still account for more than 67% of total energy consumption, and 50% of this fossil-fuel use is for room heating and domestic hot water preparation. There are still more than one million heating systems that use fossil energy [2]. Since the early nineties, heating systems based on renewable energies have been developed. Only in the last ten years have heat pumps become cost competitive compared to fossil and electric heating. The investment costs are still high and remain the main obstacle. The overall annual costs for heat pumps are, on the other hand, much lower than for fossil and electric heating systems [3]. Replacing fossil energy systems with heat pumps increases energy efficiency and the amount of renewable energy used for room heating and domestic hot water. For these reasons the Swiss government has created a strategy and a set of tools based on direct and indirect measures [4] to support the development of Swiss heat pump markets, among other things. Statistical and field analysis has been carried out over a number of years to monitor the development of the HP market and HP technology. Some aspects of Swiss legislation are also helping to promote heat production technologies using renewable energies [5]. Today, the highest demand for heat pumps (70-80%) is in the new building sector, in particular for use in new detached family homes. On the other hand, heating system replacement in existing buildings is very price sensitive. In this case, energy prices are the trigger for investment in a new heating technology such as heat pumps. The oil price is currently too low to act as an incentive and so only direct measures will trigger further development in this sector.

The present study provides a brief overview of Swiss energy strategy, including the contribution made by heat pumps. It also shows the impact of direct and indirect measures on the development of the heat pump market in Switzerland. The effects of energy prices on the payback period (PBP) will also be compared and discussed for air-water (A/W) and brine-water (B/W) heat pumps (HPs).

2 SWISS ENERGY STRATEGY

In 2007 the Swiss Federal Office of Energy developed four scenarios [6]. The first scenario "as today" assumes a continuation of current energy policy. In the second scenario, "strengthen collaboration", collaboration between the state and the economy is improved and moderate measures taken. The third scenario, "new priorities", involves setting objectives in relation to climate protection, energy efficiency and resource savings. The final scenario, "2000-Watt Society", envisages that the 2000-Watt Society (2000 watts equivalent energy consumption per capita compared to 7,800 watts today) will be achieved by 2100. For each of these four scenarios, an investigation was carried out into the development of heat and electricity production. The projections predict an electricity shortage by 2035. The scale of the shortage varies greatly according to the scenario, from 22.3 TWh down to 5.0 TWh. In each scenario the percentage of heat produced from renewable sources (wood, waste, sun, ambient heat and biomass) is increased and the amount of fossil energy consequently reduced. The percentage of renewable energy in heat production (14.6% in 2009) in 2035 also varies for each scenario, from 20% to 32%. The objectives for each scenario are firstly to avoid a power shortage and secondly to reduce the consumption of fossil fuels for heat production and thus CO_2 emissions.

Based on these four scenarios, the Swiss Federal Council edited its strategy, which is based on four main areas [7]:

- Energy efficiency — Use of new technologies in order to save energy and thus reduce energy consumption by at least 30%.
- Renewable energy — Hydroelectric power must continue to be the main source of electricity production, and must be developed along with other renewable energies for electricity and heat production out of environmental considerations.
- Electric power plants — Energy efficiency will be improved, and the use of hydroelectric power and other renewable energies expanded. However, the remaining electricity shortfall has to be met with traditional technologies able to produce a great quantity of energy. This could also be combined with imports.
- Foreign energy policy — Increase in international cooperation.

Based on this energy strategy, action plans have been drawn up. The action plan for renewable energies aims to increase their proportion of the overall Swiss energy mix from 16.2% in 2008 to 24% in 2020 [4]. This plan focuses mainly on measures in the field of heat production as a potential replacement for fossil energies. This action plan brings together measures such as: taxes, fiscal incentives, promotional activities, research and education. It primarily involves renewable energies that are already competitive or that will be so in the medium term. One measure involves substituting heating and domestic hot water preparation

installations in renovated and existing buildings with systems using renewable energies. Financial incentives will furthermore encourage owners to switch to heat pumps.

In implementing this strategy, some external factors must also be taken into account, such as [1]:

- Electricity costs — For private consumers, the price of electricity is on average EUR 0.137/kWh.
- Oil and gas costs — Price of fossil energy is on average EUR 0.053/kWh.

In this article, the main focus will be on the fourth scenario “2000-Watt Society” with the variant “renewable energies”, as well as the two first areas of the energy strategy (energy efficiency and renewable energies) for heat production with heat pumps.

3 METHODS FOR IMPLEMENTING HEAT PUMPS IN THE SWISS MARKET

Market implementation is, for clean technologies, the last link in the value creation chain [8]. The Swiss Federal Office of Energy has developed a three-step process based on the concept of the value creation chain:

- R&D — Fundamentals and applied research, including laboratory prototypes;
- Pilot and Demonstration — Knowledge and technology transfer, as well as pre-industrialized prototypes and pilot installations;
- Market diffusion — Market launch, diffusion and exportation

Such a concept has been applied for heat pumps since 1994. In the present paper the focus is on market distribution based on three main components: state regulation, direct and indirect measures.

3.1 State regulations

State regulations that partly and indirectly encourage the greater use of heat pumps are part of the regulation on energy that sets [5]:

- requirements for heat production, such as restrictions on the use of electric heating systems in new buildings, which is in fact prohibited or severely restricted;
- the proportion of non-renewable sources for heat and hot water production at no higher than 80%.

Power companies are also strongly encouraged to increase generation from renewable sources and to improve overall energy efficiency [9]. If security of the power supply cannot be guaranteed in the long term, then the government may take the necessary and constraining action needed to put the required production capacity in place. Such regulation speaks in favor of replacing existing electric heating systems with heat pumps, which would mean a reduction potential of at least 6% in overall electricity consumption in Switzerland.

3.2 Direct measures

Direct measures are mainly grant programs that provide financial support when new heat pumps are installed. The global costs are the sum of the investment and operational costs. Compared to oil, gas and electric heating systems, the investment costs for heat pumps are higher [3]. Most Swiss grant programs provide financial support to partially cover the extra investment costs by at least 10% to 60% [10] in order to decrease the payback period.
The results of the grant program for replacing accumulation electric heating systems with heat pumps will be presented in the next section. The overall amount made available for this program was 7.7 million Euros, with the following subsidies:

- Air-water heat pump (A/W-HP) — EUR 2,500.- per installation
- Brine-water heat pump (B/W-HP) — EUR 6,154.- per installation
- Water-water heat pump (W/W-HP) — EUR 6,154.- per installation
- Bonus for the distribution system (for decentralized unit) — EUR 2,300.-

The program was launched in March 2009 and all requests had to be submitted by 30 June 2009. Only installations with the “Gütesiegel” quality label were eligible for a grant.

3.3 Indirect measures

Indirect measures also play an important role in the promotion of heat pumps. Measures such as information and communication, education, research, development and demonstration, and the use of energy and heat recovery are clearly defined in the Swiss Energy Act [9]. An initial program based on these indirect measures and entitled “Energy 2000” was implemented between 1990 and 2000. It was followed by the “SwissEnergy 2001-2010” program that was launched in 2001, the second part of which ended last year (2010). The objectives of the “SwissEnergy” program were to [11]:

1. reduce CO_2 emissions by 10% by 2010 compared with 1990 in accordance with Swiss CO_2 legislation;

2. limit the increase in overall electricity consumption to a maximum of 5% between 2000 and 2010;

3. increase the contribution of renewable energy to electricity and heat production by 0.5 TWh and 3.0 TWh respectively.

A network of partners has been created to help carry out indirect measures. In 1993 the Swiss Heat Pump Association (SHPA) was set up in this context and today comprises five sectors:

- Information, Consulting and Communication
- Education
- Quality Management
- Standards and Technology
- Politics and International

The Swiss Heat Pump Test Center (SHP-TC) was also set up during the mid-nineties in order to test heat pumps according to the standards EN 255 and EN 14511 and to verify their conformity to the European “Gütesiegel” (GS) quality label [12].

The role of indirect measures is to support direct measures by ensuring high quality standards and high reliability of heat pump installations, the main objective being to achieve 100% customer satisfaction. The impact of indirect measures based on market and field statistics and analysis are also presented in the next section.

4 RESULTS

4.1 Direct measures

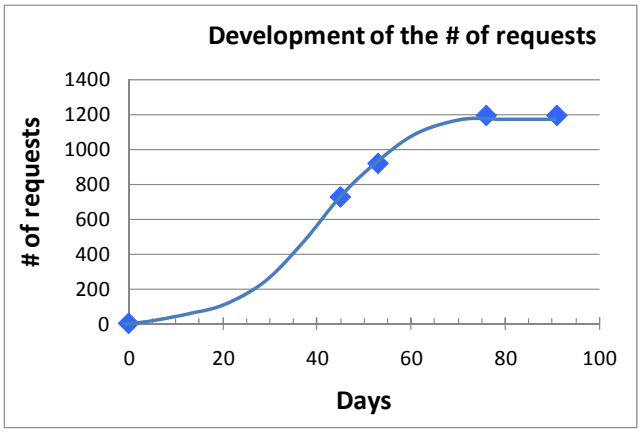

Figure 1: Grant program 2009 - Development in the number of requests

Figure 1 shows the development in the number of the requests for the replacement of accumulation electric heating systems during the 2009 grant program. The program had to be stopped before its official end (June 30th 2009), because all the grant money available had already been allocated by June 15th 2009. The proportion of each heat pump type installed reflects the size of the grant for the different types of pump:

- 67.4% for B/W and W/W-HPs
- 32.4% for A/W-HPs

B/W-HPs outstripped A/W-HPs due to the favorable financial conditions and their several advantages (less noise, less space, higher efficiency). The situation is the opposite in the liberalized market. The 2009 grant program generated a total heat capacity of 17,466.6 kW for 1,332 installations (including 143 wood heating systems which were also part of the program), representing average power production of 13.1 kW per installation.

A total of 100 installations (which corresponds to approximately 10% of the overall number of units installed within this grant program) was randomly selected from all over Switzerland in order to quantify overall consumption and consumption savings before and after the replacement of the heating system with the HP. The owners of the installations were directly contacted by the experts of the SHPA, who visited them and collected the required data. The results are shown in Table 1. Ten of the 100 previously tested installations were checked in more detail for:

- Heating power
- Brine length and linear heat capacity (for B/W-HP)
- Air output (for A/W-HP)
- Coefficient of Performance (COP)

The results are shown by Table 2. The B/W-HP has an average COP value (4.5) 24.4% higher than that of an A/W-HP (3.4). Such a difference was expected. The average length of the brine is 174.2 meters, which is within the standard brine length in Switzerland.

Table 1: Overall consumption and consumption savings of 100 installations in the 2009 grant program

Installation type	# controlled installations	Overall consumption before replacement	Overall consumption after replacement	Overall consumption savings		Average overall consumption savings per installation
(-)	(-)	kWh/y	kWh/y	kWh/y	(%)	(kWh/y)
air/water	26	381'658	167'870	213'788	56%	12'576
brine/water	72	1'321'505	546'421	775'084	59%	14'092
water/water	2	42'364	20'520	21'844	52%	10'922
TOTAL	100	1'745'527	734'811	1'010'716	58%	13'658

Table 2: Detailed results of 10 installations in the 2009 grant program

Installation Nr.	Heat pump type	Heating power	Brine length	Brine linear heat capacity	Air output	COP	
	(-)	kW	(m)	W/m	m3/h	A2/W35	B0/W35
1	air/water	11.3			3500	3.77	
2	air/water	11.6			4000	3.52	
3	air/water	14.9			5500	3.1	
4	brine/water	8.2	175	37.1			4.82
5	brine/water	8.4	150	43.9			4.62
6	brine/water	16.7	275	47.6			4.64
7	brine/water	16.9	2 x 160	39.1			3.86
8	brine/water	7.2	140	39.6			4.39
9	brine/water	9.5	170	43.9			4.61
10	brine/water	8.1	150	42.0			4.5

The key figures of the 2009 grant program for replacing accumulation electric heating systems with heat pumps can be summarized as follow:

- Total installed units (incl. wood heating) 1,332 units
- Total installed heating capacity 17,466.6 kW
- Average installed capacity per unit 13.1 kW
- Total energy savings 17,291,934 kWh/y
- Cost of energy savings per kWh (Amount of the program EUR 7.7 m) EUR 0.44/kWh
- Average energy savings per unit 12,981.9 kWh/y
- PBP B/W-HP (without grant) 9.3 years (16.8 years)
- PBP A/W-HP (without grant) 6.8 years (9.6 years)

$$PBP[year] = \frac{(IC_{HP} - IC_{OHS})[EUR]}{((CAPEX_{OHS} + OPEX_{OHS}) - (CAPEX_{HP} + OPEX_{HP}))[EUR/year]} \quad (1)$$

where

IC_{HP}, IC_{OHS} Investment cost of heat pump (HP) and other heating system (OHS) in EUR
CAPEX, OPEX Annual capital and operational expenditure in EUR per year

The payback period (for a life time of 20 years and at an interest rate of 5%) was calculated using eq. (1) with the following investment (maintenance) costs for B/W-HPs, A/W-HPs and electric heating: EUR 26,153 (EUR 77.0/y), EUR 21,000 (EUR 154.0/y) and EUR 12,300 (EUR 0.0/y) respectively [3].

Replacing accumulation electric heating systems with heat pumps resulted in power savings of 56% to 59%. A grant that covers 60% of the extra investment costs means PBP can be reduced by 30% to 45%. Direct measures are expensive (EUR 0.44/kWh). However, they provide direct results over a short period of time (from 12 to 24 months).

4.2 Indirect measures

The impact of indirect measures on the HP market was quantified by examining:

- the development of the Coefficient of Performance (COP)
- the development of the seasonal COP
- overall maintenance costs and availability of the installation

The seasonal COP (SCOP) is defined as follow [13]:

$$SCOP = \frac{Q_{HP} - Q_{HL}}{W_{HP}} \quad (2)$$

where (annual values)

Q_{HP} Energy quantity produced by the HP
Q_{HL} Heat losses
W_{HP} Overall energy consumption of the HP

The measurements taken at the SHP-TC on new heat pumps show that the development of the average COP for A/W-HPs and B/W-HPs are 3.7 and 4.5 respectively [12].

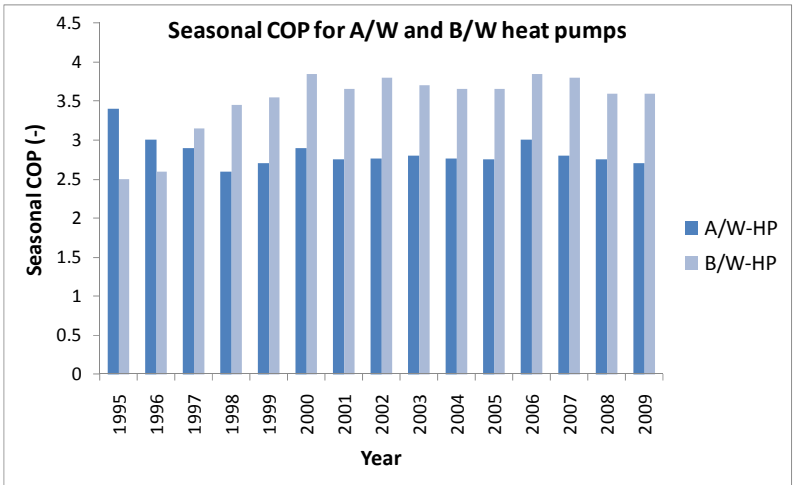

Figure 2: Development of the seasonal COP of A/W-HPs and B/W-HPs

Figure 2 shows the development of the seasonal COP (eq. 2), for which average values for A/W-HPs and B/W-HPs are 2.7 and 3.6 respectively [13]. The SCOP of B/W-HPs shows an increase due to the improvement of the performance of HPs and then a stagnation as the COP of HPs has not improved significantly since 2000 [12]. The behavior of A/W-HPs is the opposite, with a decrease of the SCOP before the plateau. This is explained by the small number of installations at that time (fewer than 10 installations in total between 1995 and 1997), which reduces the meaning of the statistics over these three years. The SCOP values are only indicative in this case and over this period.

The average reduction between the seasonal COP and the COP is between 20% and 27%. This reduction is due to the connection of the heat pump to the other components and aggregates of the heating system that also consume some additional electrical energy. The field analysis shows that the overall maintenance costs remain low, at an average of EUR 92 ± 70 per year, and the availability of the installations is higher than 99.5% for an overall working time of 2,127,783 hours (all 138 installations included) [13].

Indirect measures have helped to improve the quality of installations to a high level (low overall maintenance costs and high availability). Their effects on improving the performance of heat pumps (as components) and heat pump installations (as systems) have stagnated since 2000, after a significant increase in the late nineties.

4.3 Development of the Swiss heat pump market

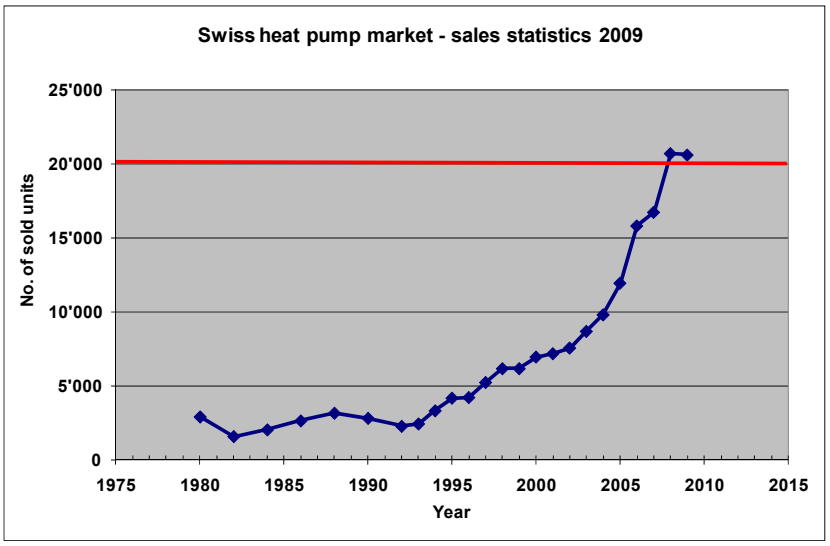

Figure 3: Swiss HP market - Development of the yearly sales

Figure 3 shows the increase in the number of units sold per year [14]. They are some important milestones to point out that have had an effect on the growth of the Swiss heat pump market, such as:

- Launch of the Energy 2000 program from 1990 until 2000
- Creation of the Swiss Heat Pump Association in 1993
- Launch of the SwissEnergy program from 2001-2005 for part one and 2006-2010 for part two
- “Peak oil” price in summer 2008
- 2009 grant program

Table 3 shows the market growth of heat pumps in new and existing building market segments in closer detail [14]. Growth in the new building market has stagnated (since 2007) and even decreased (2009). The growth in the existing building market has taken over, with a peak in 2008.

Table 3: Swiss HP market – Market growth from 2004 to 2009

Year	New buildings		Existing buildings (replacement of existing heating systems)		Total	
2004	7992	**Growth**	1880	**Growth**	9872	**Growth**
2005	9399	**17.61%**	2537	**34.95%**	11936	**20.91%**
2006	12607	**34.13%**	3199	**26.09%**	15806	**32.42%**
2007	13768	**9.21%**	2954	**-7.66%**	16722	**5.80%**
2008	15025	**9.13%**	5645	**91.10%**	20670	**23.61%**
2009	14248	**-5.17%**	6348	**12.45%**	20596	**-0.36%**

In 2009 the sales percentage per heat pump type in the liberalized market was [14]:

- 56% A/W-HP
- 41% B/W-HP
- 3% W/W-HP

The A/W-HP has the highest market share, in contrast to the 2009 grant program. This fact is easy to explain if we look at the PBP, as the investment costs of an A/W-HP are lower than those of the two other types of heat pump (B/W and W/W-HP), irrespective of the oil price. This is shown in Figure 4.

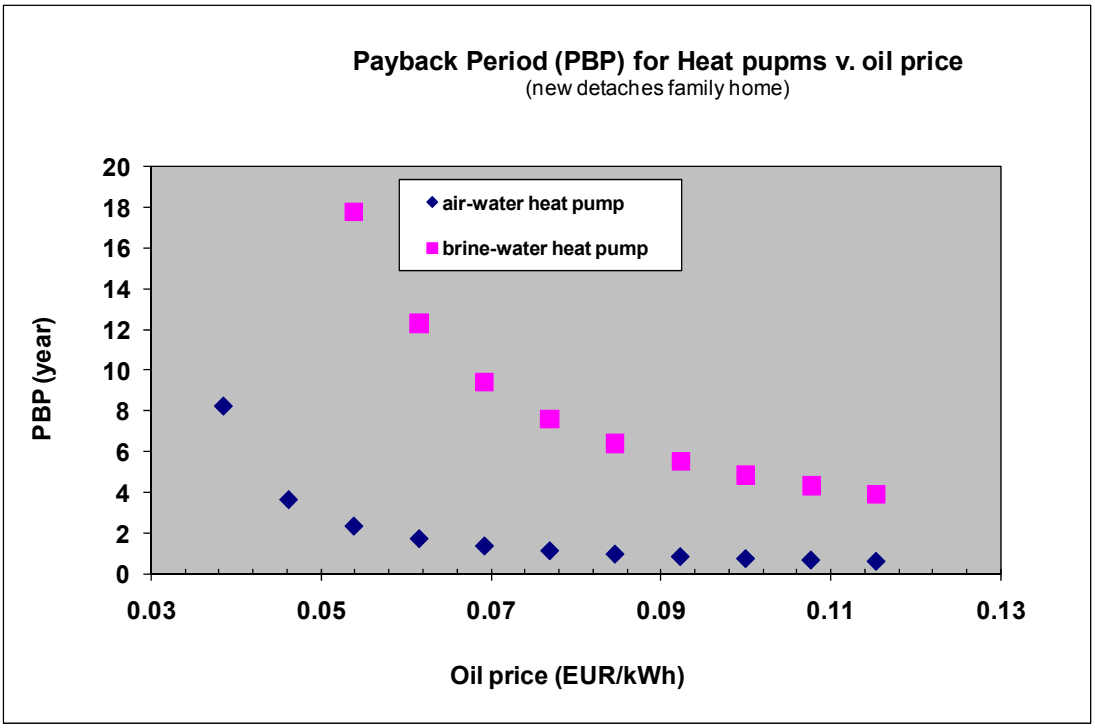

Figure 4: PBP in relation to oil price for A/W-HPs and B/W-HPs in a new detached family home

The payback period (for a life time of 20 years and at an interest rate of 5%) was calculated (eq. 1) based on the following investment and maintenance costs for oil heating: EUR 20,000 and EUR 600/y respectively [3].

The development of the Swiss HP market has been quite dynamic in the past few years with a yearly growth up to 32.4% in 2006. More than 20,000 HP units were sold for the first time in 2008. This development in HP sales is the result of the different direct and indirect measures that have been implemented since the early nineties ("Energy 2000"," Swiss Energy" and grant programs similar to the one in 2009).

5 POTENTIAL AND PERSPECTIVES

5.1 Potential 2035

The Swiss potential of heat pumps can be assessed based on [2,15]:

Number of new buildings with accommodation	16,563 per year (average from 2004-2009)
Number of existing heating systems	814,827 oil 200,187 gas 166,248 electric

Taking a market share for heat pumps of at least 70% for the new building market sector and 50% for the replacement of existing fossil and electric heating systems, then the market potential for 2035 is more than 880,000 heat pumps.

5.2 Perspectives 2020

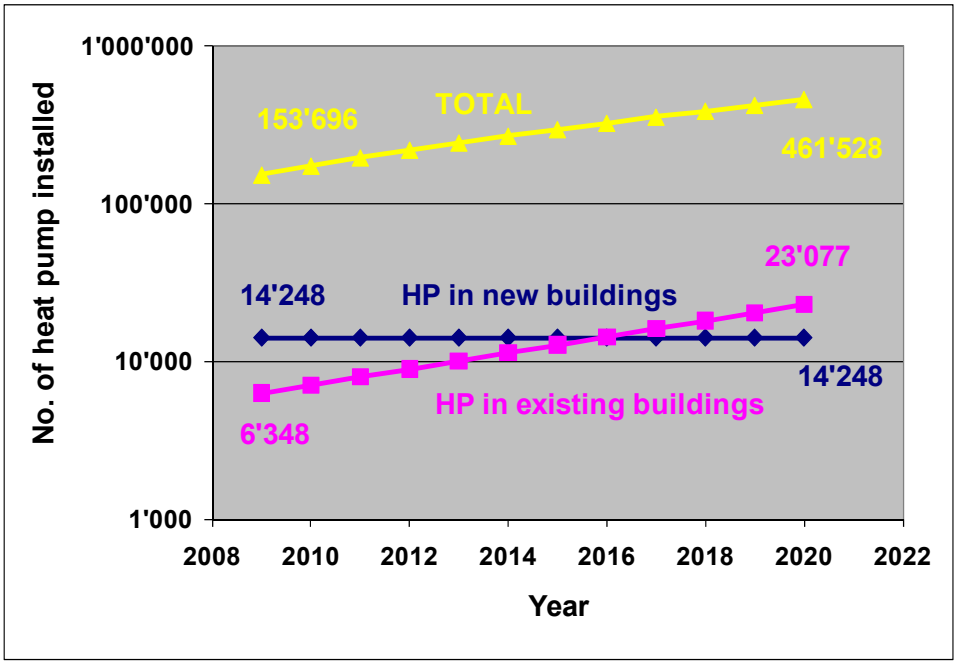

Figure 5: Projected development of yearly sales and of the number of heat pumps installed in Switzerland by 2020 [14]

The objective for 2020 is 400,000 units installed [14]. Some projections have been made based on the sales statistics presented in Table 3, making the following assumptions:

- Yearly sales for new buildings will remain steady 14,248 units/year
- Growth in yearly sales for the replacement of fossil units 12.45%
- Base line (no. heat pumps installed in 2009) 153,696 units

The projections for the development of the number of heat pumps installed by 2020 (461,528 units) are (see Figure 5):

- 153,696 units installed in 2009 (base line)
- 156,728 units installed in new buildings
- 83,124 units to replace electrical units (50% of existing electric heating)
- 67,980 units to replace fossil heating systems

The priorities for the Swiss HP market for the next ten years are: to maintain the 70-80% market share in new buildings and to encourage and boost the replacement of electric and fossil heating systems in existing buildings. The replacement of fossil units will however greatly depend on the development of the oil price.

6 CONCLUSION

Heat pumps are an important component of the Swiss energy strategy to reduce dependence on fossil fuels, and to increase energy efficiency and the proportion of renewable energies used for heat production.

Heat pumps are cost competitive relative to oil, gas and electric heating systems in the new building market sector, but still have the main drawback of involving higher investment costs.

Successful expansion of the market depends on the effectiveness of three components: state regulation, direct and indirect measures.

Direct measures are grant programs that meet a certain percentage of the extra investment costs (min. 10% and max. 60%) in order to decrease the payback period by up to 45% and to provide an incentive to invest in heat pumps.

Indirect measures such as information, communication, quality management, education and standards should support the direct measures by providing reliable systems.

The heat pump potential in Switzerland is estimated at up to 880,000 units.

The projections show that at least 400,000 HP units could be installed in 2020 and that replacing heating systems running on non-renewable energy in existing buildings will be the focus for the next ten years.

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