Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Annex 42

Heat Pumps in Smart Grids

Market overview: Country report for Switzerland

Appendix to the Final report

Operating Agent: The Netherlands

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Market overview

Country report for SWITZERLAND

Report compiled by

Lucerne University of
Applied Sciences and Arts

HOCHSCHULE
LUZERN

ABSTRACT
This appendix provides the detailed summary report discussing the market overview for Switzerland.

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List of abbreviations

BFE	Bundesamt für Energie (Federal Office of Energy)
CCPP	Combined cycle power plants
EICom	Federal Electricity Commission
ERA	Energy reference area
EU	European Union
GDP	Gross domestic product
ICT	Information and communication technology
KEV	Kostendeckende Einspeisevergütung (cost-covering feed-in tariffs)
MoU	Memorandum of Understanding
MuKEN	Mustervorschriften der Kantone im Energiebereich (model rule for all Canton in the field of energy)
ORC	Organic Rankine Cycle
UVEK	Eidgenössisches Department für Umwelt, Verkehr, Energie und Kommunikation (Federal Department of the Environment, Transport, Energy and Communications)
EBF	Energiebezugsfläche (energy-related surface)

1 Overview of the Swiss Energy Sector

1.1 Overview of main challenges in Switzerland

According to the 2013 overall energy statistics from the BFE, Switzerland consumes 1.165 million tera Joules (TJ) of energy from primary sources (gross consumption). The most important energy sources are crude oil or petroleum products 43.3 %, nuclear fuel 23.3 %, hydropower 12.2 %, and gas 11.1 %, as well as garbage and industrial waste 5 %. This results in a dependence on imported sources of nearly 80 %. The conversion of primary energy into secondary energy carriers is associated with losses of about 25 %, so that the final consumption is 0.91 million TJ. Switzerland's main secondary energy carriers are 33.5 % fuels (diesel, petrol and aviation fuels), 23.8 % electricity, 18.8 % heating oil and 13.5 % gas [1].

With a primary energy dependence on foreign sources of around 78%, Switzerland covers only one-fifth of its consumption from domestic energy sources. This 22 % is shared between hydropower, energy wood, waste and industrial waste as well as other renewable energies (solar, wind, biogas, bio-propellants, and environmental heat). The use of hydro power, with around 54.5 % of the domestic share represents by far the most important energy source in the Switzerland. The other renewable energy sources account for a share of around 7 %. The energy consumption is almost half as high as the world average per unit of GDP and is distributed about one-third each between transport, households, and industry and services [1].

The electricity production in Switzerland is carried out 36.4 % in nuclear power plants and around 3.9 % in conventional thermal power plants. So now to generate electricity, Switzerland is approximately 41 % dependent on imports of energy sources (uranium, oil, and gas). About 58 % of electricity production comes from the use of hydropower, about 1.5 % from the use of new renewable energy sources (biomass, solar, wind and treatment of waste) [1].

Energy perspectives have been the basis of all Switzerland's energy policy choices. Since the creation of the total energy concept in the mid-1970s, these perspectives are periodically updated. The Federal Council decided on 21 February 2007, on the basis of "Energy 2035", to support its energy strategy on the four pillars of energy efficiency, renewable energies, large power plants and an active foreign energy policy. As a result of the accident in the Fukushima nuclear power facility, the Federal Council commissioned the UVEK on 23 March 2011 to update the "Energy 2035" from the year 2007 on the basis of three power supply variations. On 25 May 2011, the Federal Council decided to abandon new nuclear power plants and confirmed the turnaround in energy policy. The contents of this turning point are: a reduction of the consumption of fossil energy (oil, gas, and petrol), no nuclear power and stabilization of power consumption. By 2050, Switzerland seeks to be a 2000-watt and a 1-1.5 ton CO_2 society. In comparison, today each and every Swiss annually consumes 6400 watts of power and produces around 6 tonnes of CO_2.

With the Energy Strategy 2050 and the gradual phasing out of nuclear energy, gas will play an even more important role in Switzerland to ensure the energy supply. Since hardly any mineable domestic deposits are present, the demand of about 30 TWh per year is 100 % covered by imports. For this purpose, there are long-term supply contracts with partners in the EU. Switzerland purchases by far the largest part (about 67 %) of its gas from countries within the EU and Norway [2].

The Swiss electricity grid is facing major challenges. The bulk of the Swiss transmission lines were created about 50 years ago. The network will need to be partially renewed. In addition, its transport capacity is limited because the lines were originally designed for much smaller amounts of current. The substance conservation and optimum utilization of existing capacity is intended to be pursued as a priority, for example by means of smart grid and congestion management. New lines should be built only where it is necessary for the security of supply. The investment requirements of the next 10 years amount to around 3.2 billion Swiss francs [2].

Switzerland is not a current island. The supply system has historically grown by close connections with foreign countries. Therefore, security of power supply is possible only in conjunction with the European network. Switzerland's participation in the trans-European network, the construction of high-performance power grid, the design of energy infrastructure and participation in the market coupling initiatives are therefore of central importance. It is equally important that Switzerland can exercise its influence in international bodies. This is an important aspect in bilateral negotiations with the EU.

1.2 Swiss electricity generation

Swiss electricity generation, by fuel type (incl. renewables & import/export balance if available), historic trend and outlook

Due to the topological conditions, hydropower has always played an important role in Swiss electricity production. At the beginning of the seventies the Swiss also started to generate electricity in nuclear power plants. Today, nuclear energy is with 38.1 % the second most important primary energy source for the generation of electricity. To set the goal of achieving the phase-out of nuclear energy by 2050, it is therefore necessary to realize about 40 % of today's electricity production by other conversion processes.
With imports of 36.2 billion kWh and exports of 38.6 billion kWh a trade surplus of 2.4 billion kWh resulted in 2013. The proceeds from the current exports amounted to CHF 2,386 million (6.22 Rp. / kWh). For electricity imports 2,059 million Swiss francs (5.71 Rp. / kWh) were spent. Switzerland's positive foreign trade balance in 2013 fell by 42.4 % to 327 million Swiss francs (2012: Francs 771 million) [3].

Figure 1 – Electricity production by power plant (1950 – 2013).

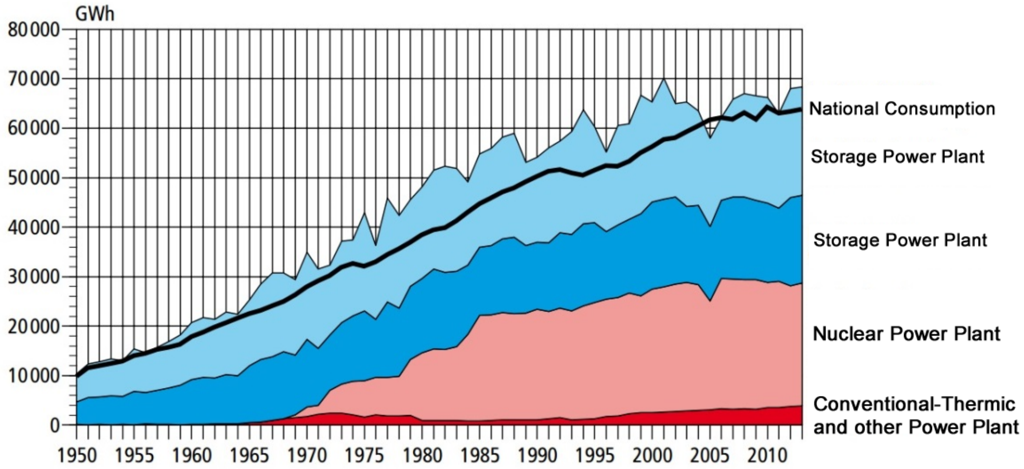
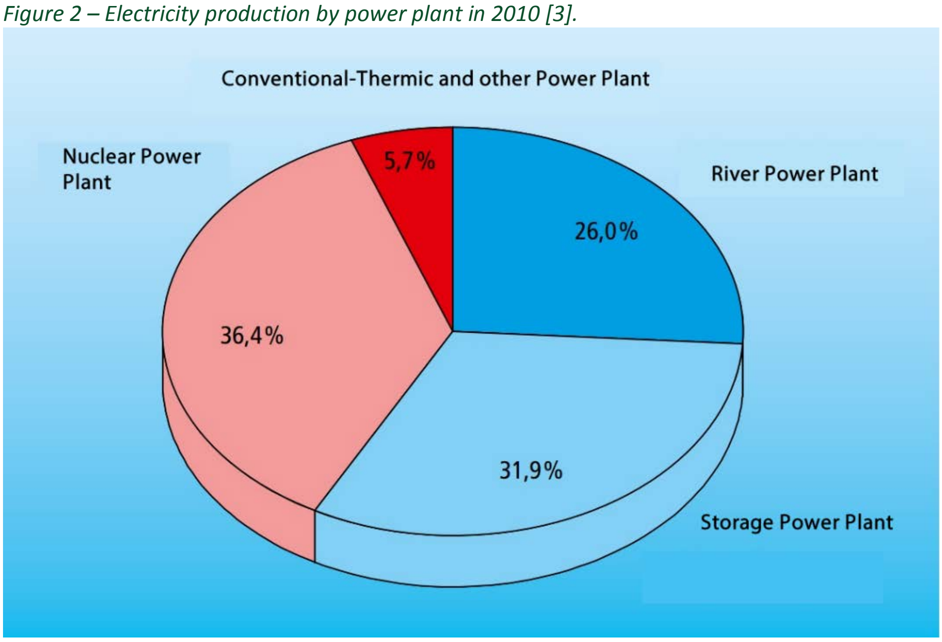


Figure 2 – Electricity production by power plant in 2010 [3].

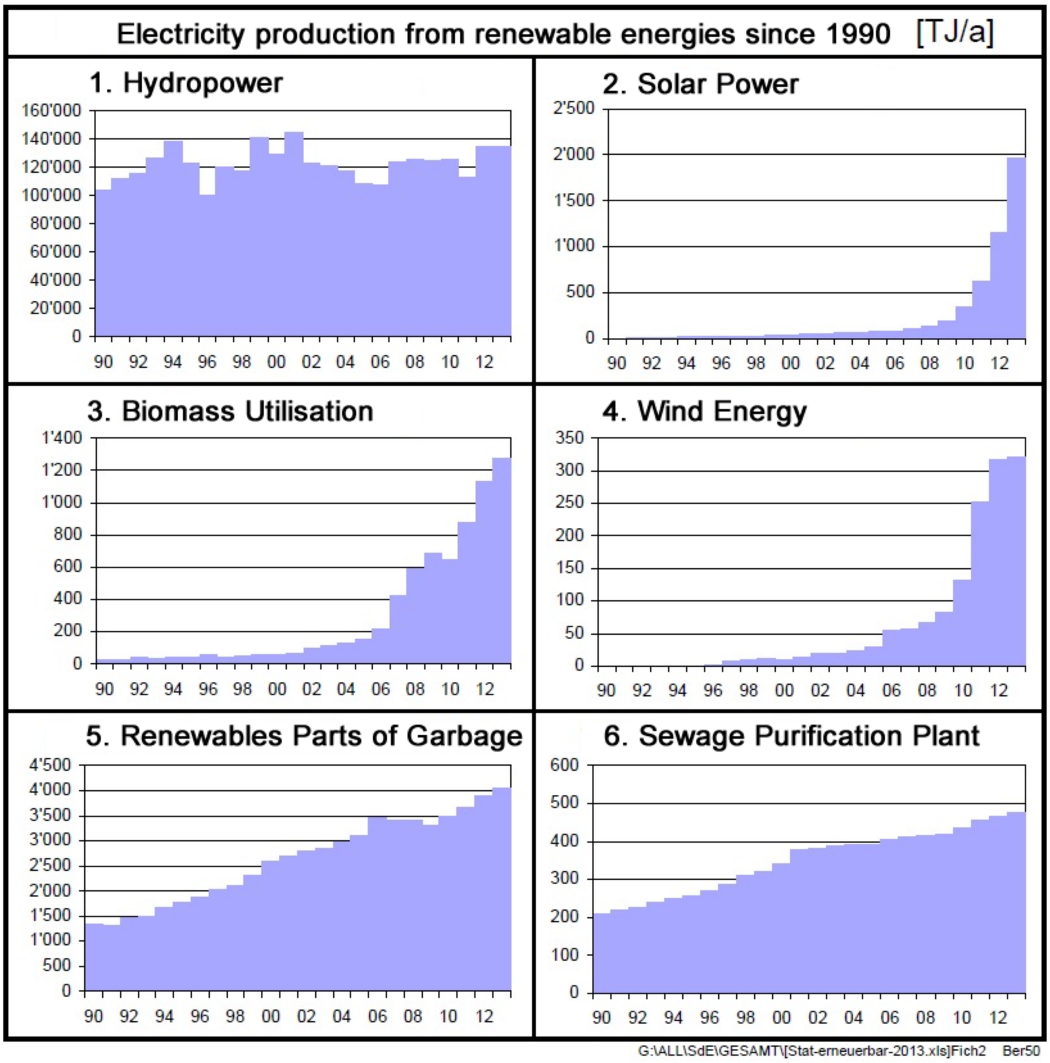


Historic development and outlook of renewable generation capacities, production and market share

The development of renewable electricity production runs quite differently in the various fields of technology since 1990. At the dominant hydropower plants, the influence of hydrological conditions is clearly visible.

In recent years, a marked increase in other technologies for renewable electricity production is observed. In solar electricity (photovoltaics) it was only in the late eighties and in wind energy, even until the mid-nineties, that the annual production of 1 million kWh was exceeded. Apart from hydropower, electricity production from renewable waste components has experienced the absolute strongest increase since 1990.

Figure 3 – Development of electricity production from renewable energy sources since 1990 [4].

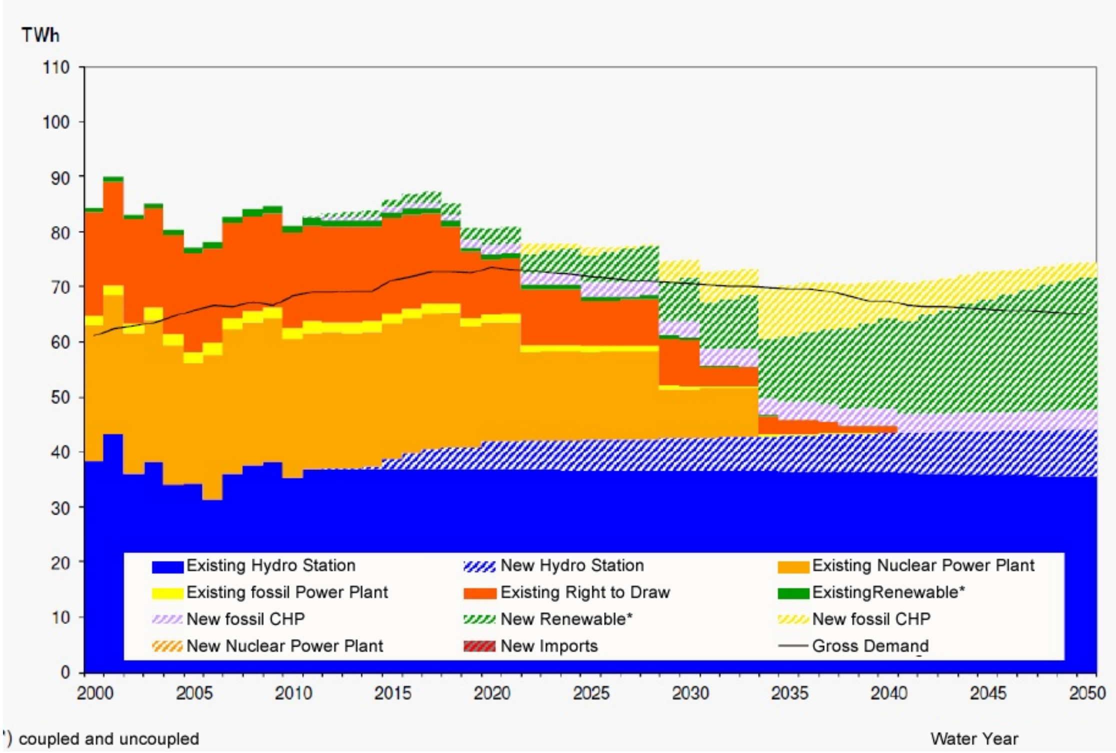


In order to estimate the future development of the energy situation in Switzerland, three electricity supply scenarios for the Federal Council were created [4]:

- Scenario 1: “Business as usual”
  Autonomous trends of the past will be observed and updated according to the current market conditions. Further on, they will be reinforced by the energy policy instruments, which are either already in force at the present time, or planned.
- Scenario 2: “Policy measures”
  The adopted measures drawn up by the Federal Council on 18 April 2012 will have been analysed, giving special consideration to their legislative basis (e.g. provisions for building standards, CO2 emission limits for new vehicles).
- Scenario 3: “New energy policy”
  The targeted policy variant, "New energy policy", examines how to achieve the target of reducing energy-related CO_2 emissions in Switzerland to around 1.5 tonnes per head by 2050.

In the "New Energy Policy" scenario it is important to recognize that the annual consumption of electricity decreases from the year 2020. There is an increase of consumption until 2020, due to the expansion of pumped storage plants. The nuclear power plants all together should be turned off by the year 2035. The resulting gap in available energy or electricity is initially closed primarily through the development of renewable energy systems and combined cycle power plants. From the year 2035, renewable energy systems will be continuously expanded and therefore replace the combined cycle power plants.

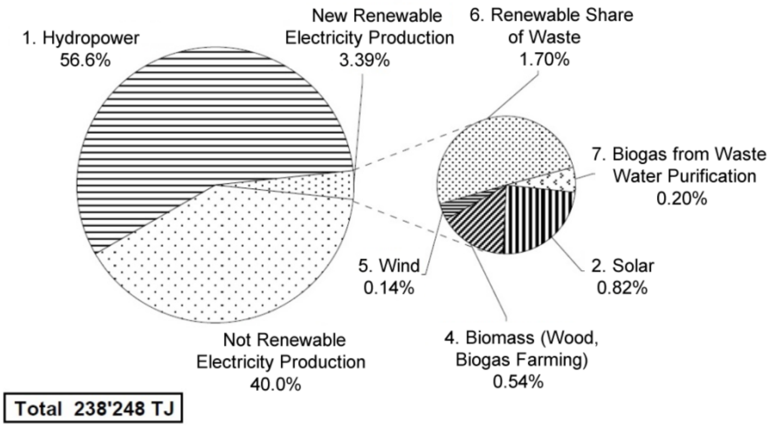
Figure 4 – Development of electricity supply by power plants up to 2050 in the "New energy policy" scenario [5].



Total available generation capacity

The entire volume of net electricity production in 2013 amounted to 238'248 TJ (equivalent to 66'180 GWh). From this domestic production 142'867 TJ (60.0 %) were from renewable sources. The vast majority comes of the use of hydropower. The contribution of solar energy, biomass, biogas, wind and waste usage amounts to 8'083 TJ, or about 3.4 % of total electricity production [4].

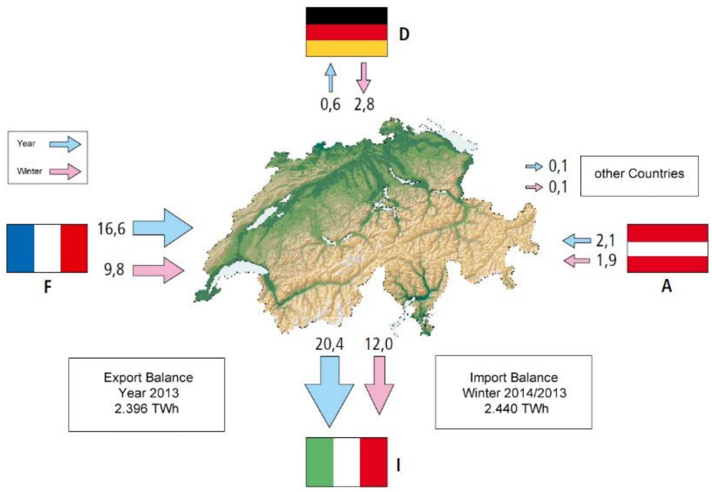
Figure 5 – Swiss overall electricity production by technology in 2013 [4].



How is peak demand met?

In Switzerland, peak loads are balanced predominately by the use of pumped storage power plants. 31.9 % of total electricity production comes from pumped storage power plants. In addition, Switzerland is a transit country for electricity and depending on the needs and excesses of electricity demands; Switzerland is constantly trading electricity with its adjacent neighbour countries.

Figure 6 – Import and export of electricity in 2013 (TWh) [3].



1.3 Swiss Energy Demand

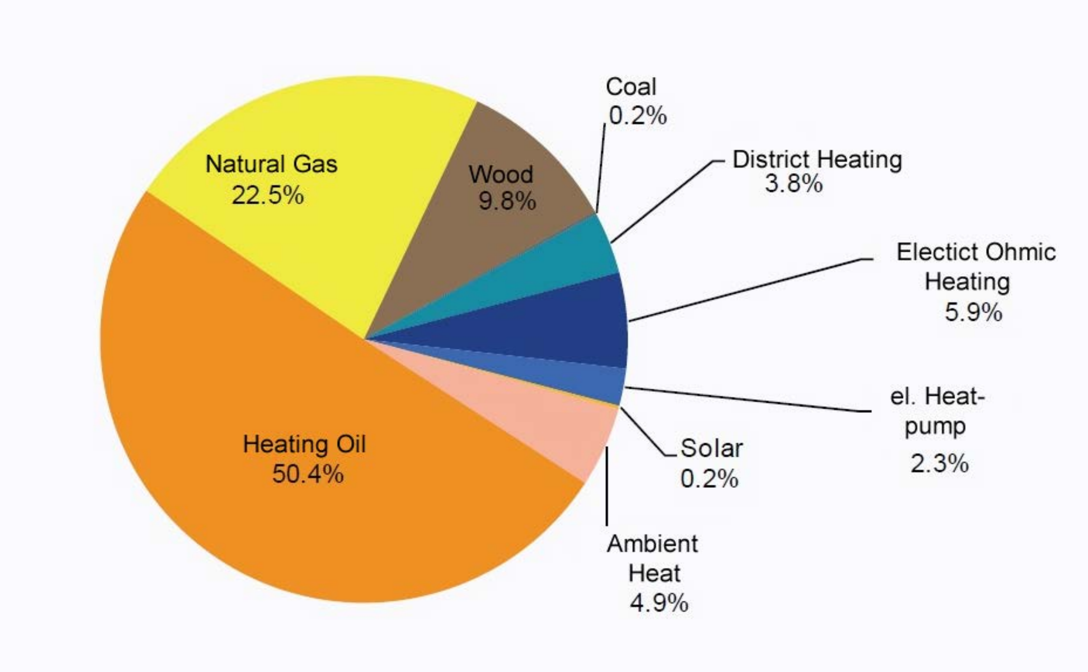
Final energy demand in the domestic heating sector (& cooling sector where appropriate) divided by fuel type [12]

In 2012, 69.7 % of the final energy consumption of Swiss households was used for space heating. Therefore the auxiliary energy consumption for the operation of facilities and heat distribution is not included.
Between 2000 and 2012, the total heated living space in Switzerland was expanded to 80.5 million m^2 ERA (energy reference area) (+ 20.9 %), representing a growth rate of 1.6 %. This does not take into account newly built areas for second and holiday homes.
With an increase of 46.5 million m^2 ERA (+ 68.8 %) the area heated by natural gas has seen the most growth in the period 2000-2012. In 2012, a quarter of the area was approximately heated with natural gas (24.5 %). The area heated by electric heat pumps has also expanded strongly (+ 38.6 million m^2 ERA; + 269 %). Solar thermal plants have seen a strong percentage growth too, with + 258 % however (vs. + 0.8 million m^2 ERA. 2,000) they are still on a very low absolute level of around 1.1 million m^2 ERA.
The area heated with fuel oil is declining: compared to 2000, it has decreased about 18.8 million m^2 (- 8.0 %). However, oil still remains the main source of energy to provide space heating. In 2012, almost half of total Swiss household space was still heated with fuel oil (46.2 %).
The average heating demand per m^2 ERA between 2000 and 2012 has decreased by 14.7 % to 332.2 MJ/m^2 and year. The average efficiency of heating systems has been increased by 6.1 % to 85.6 % in this period. The strongest growth in efficiency gains shows up in the heating systems powered by electric heat pumps and gas central heating (condensing systems).

Table 1 – Residential final energy use, by fuel type (2000 – 2012) [12].

	2000	2006	2007	2008	2009	2010	2011	2012	Δ '00 – '12
Heating Oil	109.3	108.5	93.0	99.9	95.6	105.3	78.8	86.9	-20.5%
Natural Gas	28.0	34.9	31.6	36.1	36.0	41.7	33.0	38.8	+38.9%
Ohmic Heating	10.4	11.1	10.1	11.0	10.7	11.7	9.4	10.1	-2.3%
Wood	15.5	16.7	15.2	16.7	16.6	18.6	15.1	17.0	+9.7%
Coal	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.3	-1.8%
District Heating	4.4	5.5	5.1	5.9	5.9	7.0	5.6	6.5	+46.9%
electric Heatpump	1.5	2.5	2.4	3.0	3.2	3.9	3.3	4.0	+166.9%
Ambient Heat	2.8	4.8	4.8	6.0	6.5	8.0	6.9	8.4	+203.6%
Solar	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	+229.0%
Total	172.2	184.8	162.7	179.2	175.1	196.9	152.6	172.4	+0.1%
Total weather-adjusted	191.8	189.2	188.6	188.1	187.3	186.2	184.9	183.4	-4.4%

Figure 7 – Residential final energy use, by fuel type (2012) [12].



Typical heating / cooling / electricity demand in households [12]

The total energy consumption in private households increased in the years from 2000 to 2012 by 5 PJ (+ 2.1 % according to energy statistics + 10.9 PJ; + 4.5 %). According to the model calculations the growth is mainly due to the increase of the energy consumption of other electrical appliances (+ 3.4 PJ; + 77.8 %), the most significant increase is the consumption for washing and drying laundry (+1.2 PJ; + 47.3 %). The energy consumption for other uses has changed by less than 1 PJ in the considered period.

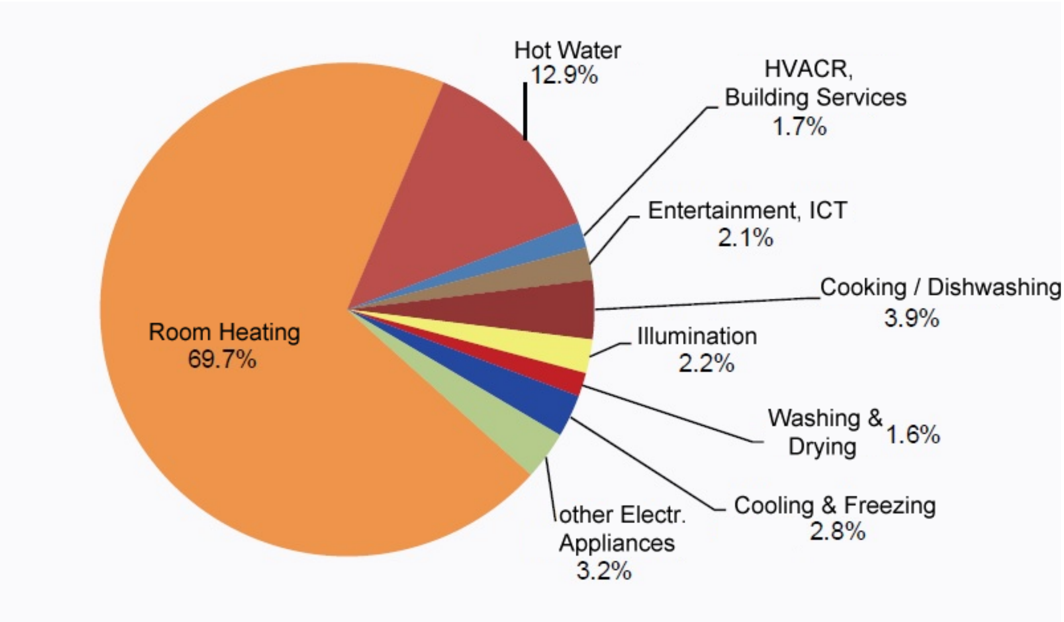
In 2012, two thirds of Swiss household energy consumption were accounted for by space heating (69.7 %). The production of hot water also had great importance for the sector's consumption (2012: 12.9 %). In contrast to space heating, hot water consumption barely reacts to the weather conditions.

Other domestic uses account for comparatively small amounts of energy. The share of the sector consumption was low: cooking including dishwashing 3.9%; other electrical appliances 3.2 %; cooling and freezing 2.8 %; illumination 2.2 %; entertainment 2.1 %; washing and drying 1.6%; and air conditioning, ventilation and building services 1.7%. However, these uses exclusively require energy of high quality (electricity).

Table 2 – Energy consumption in private households by purpose (2000 – 2012) [12].

	2000	2006	2007	2008	2009	2010	2011	2012	Δ '00 – '12
Room Heating	172.2	184.8	162.7	179.2	175.1	196.9	152.6	172.4	+0.1%
Space Heating Installed	170.5	183.1	161.0	177.4	173.4	195.1	151.0	170.8	+0.2%
Mobile heating	1.7	1.7	1.7	1.7	1.7	1.8	1.6	1.6	-4.7%
Hot Water	32.3	31.9	31.7	31.9	31.9	32.2	31.5	31.8	-1.6%
Building Services (HVACR)	3.6	4.0	3.7	4.0	4.0	4.4	3.8	4.2	+16.4%
Heating Auxiliary Energy	2.4	2.7	2.3	2.6	2.5	2.9	2.2	2.5	+5.6%
Air Conditioning	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	+30.7%
others Buidling Services	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	+51.7%
Entertainment, ICT	5.3	5.4	5.5	5.6	5.7	5.6	5.4	5.2	-2.1%
Cooking / Dishwashing	8.9	9.1	9.1	9.2	9.3	9.4	9.5	9.6	+7.7%
Illumination	5.7	6.3	6.2	6.2	6.0	5.9	5.6	5.5	-5.1%
Washing & Drying	2.6	3.4	3.6	3.7	3.7	3.8	3.9	3.9	+47.3%
Cooling & Freezing	7.1	7.1	7.1	7.1	7.1	7.1	7.0	6.9	-3.2%
other Electrical Appliances	4.4	6.1	6.3	6.5	6.8	7.1	7.4	7.8	+77.8%
Total Final Energy Cons.	242.3	258.2	235.9	253.4	249.7	272.4	226.6	247.3	+2.1%

Figure 8 – Energy consumption in private households by purpose (2012) [12].



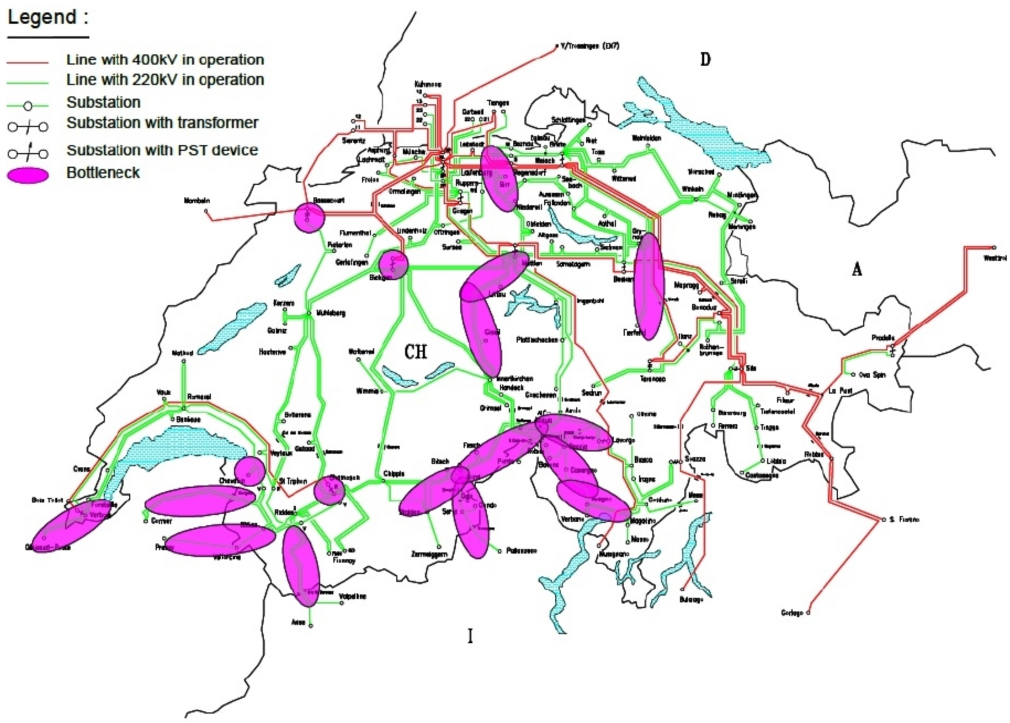
1.4 Swiss Energy Infrastructure

Electricity networks – status & outlook [1]

shows the current prevailing bottlenecks in the Swiss high-voltage grid. According to the review of the multi-year plan by the Federal Electricity Commission (ElCom), there is a need for investment in the renewal and expansion of the Swiss transmission system over the next 10 years in the amount of around 3.2 billion Swiss francs. Based on recent estimates from Swiss Grid, an investment requirement of around 6 billion francs can be expected. By 2030, or 2050 there will be additional investment required in network infrastructure. New construction or expansion of pumped storage power plants (Nant-de-Drance, Linth Limmern, Lago Bianco, KWO plus, etc.) also places new demands on the network infrastructure.

However, it is not enough to simply strengthen transport capacity. Switzerland is facing additional new technical challenges such as a quickly growing number of decentralized power plants feeding electricity from renewable sources into the grid. Accordingly, appropriate backup capacity must be provided. It is also necessary - particularly due to the realignment of the energy strategy - to redesign the interplay between the band energy and peak current. Information and communication technologies should therefore be used to expand the networks to become intelligent, so-called "smart grids". From the perspective of security of energy supply, “smart grids” are extremely important.

Figure 9 – Bottlenecks in the Swiss high-voltage grid in 2010 [1].

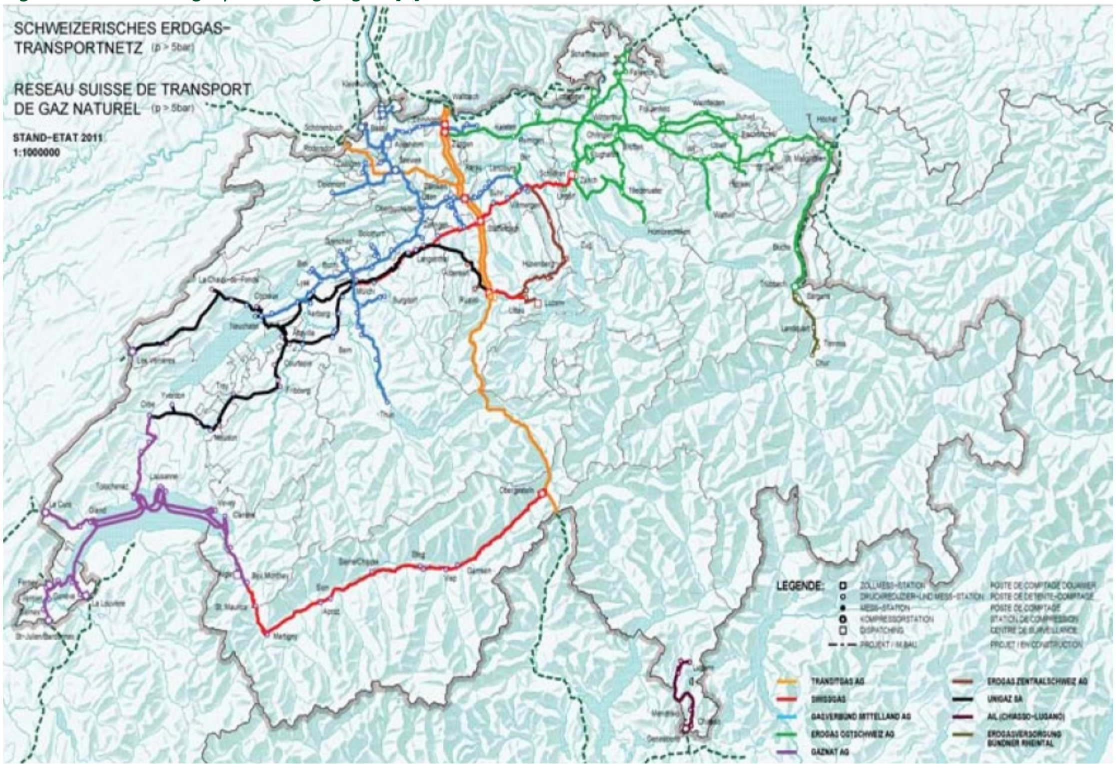


Gas network + heat network - current extent and outlook

With a share of 13 % in energy consumption natural gas is an important energy source in Switzerland, even if it is under-used in comparison to the European average [1]. With the implementation of Energy Strategy 2050 and the gradual phasing out of nuclear energy, gas will play an even more important role to ensure the energy supply.

The backbone of the Swiss gas infrastructure is the 1974 commissioned north-south transit line (transit gas, marked in orange on the map of Figure 9) heading from Wall Bach (AG) to Griespass (VS). Over approximately three-quarters of the country's consumption is imported through this transit line, while the remainder is imported on various cross-border connection points on the regional high-pressure networks. The capacity of the Swiss high-pressure gas transport network is sufficient for the foreseeable future. The transport capacity of transit gas line was doubled between 1998 and 2003 from 9 to 18 billion cubic meters per year, which is five times the current Swiss annual gas consumption. The national network and the supply lines to the Swiss border are dimensioned so that they could cope with a possible increase in consumption by gas combined cycle power plants (CCPP). Currently, no extensions of the high-pressure gas network are planned.

Figure 10 – Swiss high-pressure gas grid [1].



1.5 Swiss Energy Policy

Major policies affecting the electricity sector, including renewable energy/CO_2 reduction targets

After the radioactive accident in Fukushima, the existing energy outlook for 2035 came under critical scrutiny and has been adapted to macroeconomic (GDP and population) and energy industry conditions. The Federal Council decided in May 2011 that the existing nuclear power plants will not be replaced at the end of their life. On the basis of this decision, the three scenarios: "Business as usual", "Federal actions", and "New energy policy" were created. These were briefly described in chapter 1.2. The Energy Strategy 2050 will be implemented in stages. According to the Swiss Federal Council decision of 25 May 2011, the energy strategy for 2050 is aiming towards the medium to long-term objectives of the "New energy policy". This is not being put into action in Switzerland alone, but is connected to a concerted international energy policy.

According to the order of the Federal Council to the UVEK (Federal Department of the Environment, Transport, Energy and Communications) of 18 April 2012, a first package of measures until 2020 was drawn up, which focuses on the "Federal actions“ scenario.

Table 3 – Assumptions for the scenarios "Business as usual", "Federal actions" and "New energy policy" [5].

<table>
<tr><th>Business as usual</th><th>Federal actions</th><th>New energy policy</th></tr>
<tr><td colspan="2">Private households, buildings</td><td rowspan="7">• Strategic overall aim
• CO_2 emission of 1 – 1,5 t per head until 2050
• Limited sustainable biomass potential
• Derived strategic Requirements
• Efficiency ahead of renewable
• Electricity efficiency is essential
• Electro mobility is necessary
• Small changes in the amount of traffic
• Bio mass mainly in transport of goods and CCPP plants</td></tr>
<tr><td>• Moderate updating of MuKEN
• Building program 200 Mio Fr.
• Promotion renewable energies and building program
• Moderate update for standards</td><td>• Aggravation of MuKEN
• Replacement of resistance heater
• Building program
  ○ 300 Mio Fr. from 2014
  ○ 600 Mio Fr. from 2015
• SIA 380/4 obligatory in all multifamily houses and residential buildings</td></tr>
<tr><td colspan="2">Industry and service</td></tr>
<tr><td>• Competitive tender 16 – 27 Mio. Fr./a
• Voluntary commitment</td><td>• Competitive tender 100 Mio. Fr./a
• Bonus for efficiency and CO_2 tax
• Optimization of operation
• Promotion ORC-unit</td></tr>
<tr><td colspan="2">Traffic</td></tr>
<tr><td>• EU Emission limits (130 or 95 g CO_2/km) achieve until 2030
• Improvement of the efficiency of the transport design</td><td>• Aggravated values for emission limits (130 or 95 g CO_2/km until 2020, 35 g CO_2/km until 2050)
• Traffic organisation</td></tr>
</table>

Major policies affecting the heating sector, including building regulations and renewable energy/CO_2 reduction targets

Building program and cantonal programs: The building program supports in all of Switzerland improving the insulation of buildings. In most cantons, the transition to renewable energy heating systems such as heat pumps, solar or wood energy plants is encouraged. The cantonal energy offices advise on these cantonal support measures. The federal government itself has no direct funding for such projects. However, it supports the cantonal funding on contributions under the building program initiated in 2010. In addition to the support provided by the federal government and the cantons, there are a number of other funding opportunities through communities, energy suppliers and banks.

Heat pump related incentives/policies etc.

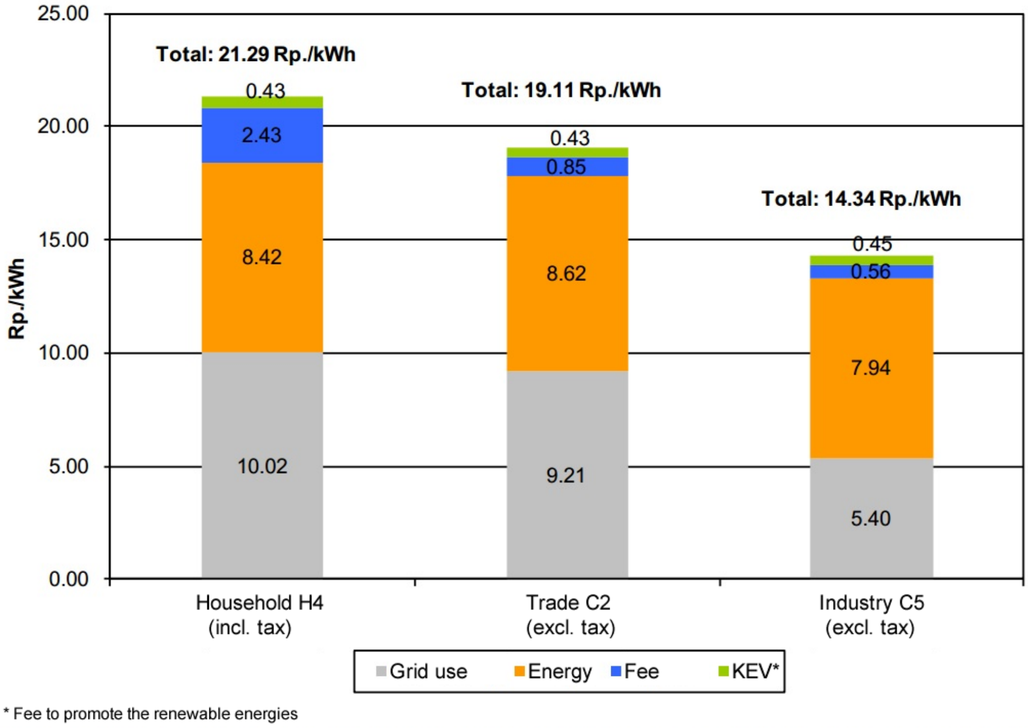
There are no additional specific heat pump incentives apart from the upper mentioned building program.
Research and development of heat pumps and heat pump related projects are funded by the Swiss Federal Office of Energy SFOE within a program specifically dedicated to heat pump related topics.

1.6 Energy Prices, Tariffs & Structures

Electricity prices, including price structure (generation costs, network charges, taxes & levies) [6]

The price of electricity is made up of four components: network usage charges, energy prices, taxes and benefits to the community as well as cost-covering remuneration KEV. For households and businesses, the percentage of network usage charges on electricity price is highest - in 2010 it made up around 50 % of the electricity price. For industry, the cost of network usage is set at more than one-third of the electricity price. The components of taxes and benefits as well as KEV contribute to a lesser extent (total 10 % to 15 % of households) in the total electricity tariffs. The smallest difference between the individual types of consumers is in the price of the actual energy.
The current prices for Swiss households are slightly below the average of those in the EU. However, the electricity prices for industry are slightly above the EU average.

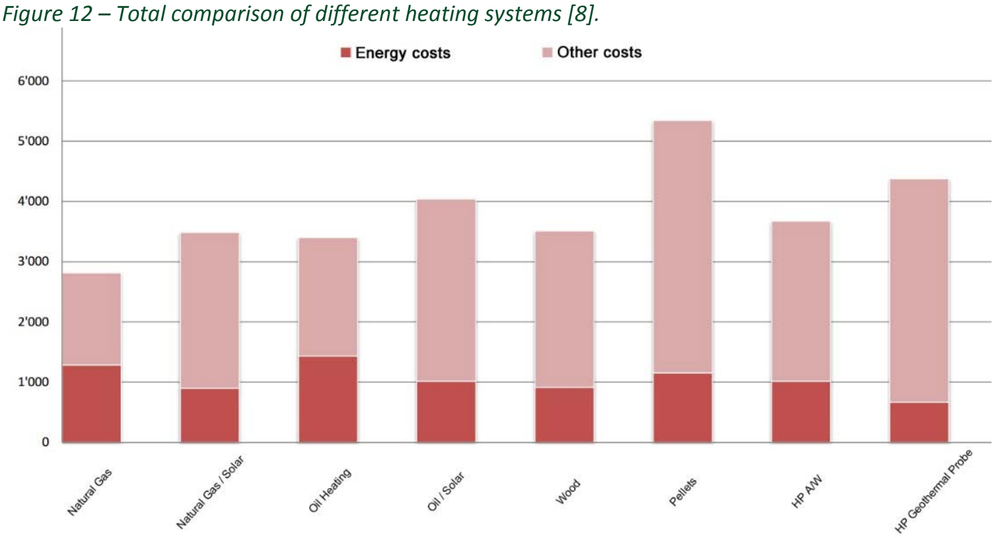
Figure 11 – Composition of electricity prices in 2010 [6].



Gas prices / prices of other competing heating technologies

Basically, a cost comparison between different heating systems is possible only in specific individual cases, because there are many factors playing a role. It would be wrong to make a comparison based only on the pure energy price per kWh, because energy costs usually make less than half of the total cost. Therefore, a complete comparison must also include the acquisition cost, the costs of premises, maintenance, servicing and inspections.

Figure 12 – Total comparison of different heating systems [8].



What types of tariffs are available?

In Switzerland, there are a high and a low tariff. The high tariff takes effect during the day from around 07.00 am until 09.00 pm. The rest of the day is low tariff.

There is also segmentation into three categories of energy users. The first group consists of households and community usage; the second and third groups are for trade, business and industry users, separated by the quantity of their energy use. The effect is to offer a lower price to companies that have a high demand for energy.

2 Analysis of the Swiss housing stock & heating market

2.1 Overview of main challenges in the Swiss market

A big challenge is to show operators and users how much energy their appliances consume and how much energy, and consequently how much money, they can save. The Federal Department of Energy (BFE, Bundesamt für Energie) has created the Energy Swiss platform to inform consumers about energy matters and respond to questions.

Further, the Federal Department of Energy is intended to promote the use of renewable resources, for example with financial support such as the "cost-covering remuneration for feed-in to the electricity grid" (KEV, kostendeckende Einspeisevergütung), which is used to promote renewable energy. Other tools to promote the use of renewable energy sources are regulations such as the "Model Regulation of the Canton in the Energy Sector" (MuKEn, Mustervorschriften der Kantone im Energiebereich), which regulate the amount of non-renewable energy sources.

A new law allows the use of direct electric heating in the building of new housing only in special cases. However, the replacement of around 800,000 warm water storage systems with direct electric heating systems is another challenge. At the moment, the search for the most economical and ecologically friendly solution is ongoing [17].

In new buildings and renovated older buildings insulation is very good as a result of MuKEn regulations, which reduce energy loss to a minimum. So, there is no reason to build houses with a greater level of insulation. Now the focus is on energy generation and distribution. The targets are: to promote the use of renewable energy; to increase the efficiency of energy conversion; and to reduce the irreversibilities. Current heating systems are controlled by the daily household demands. However, because of the heat inertia inherent in buildings, the temperature and climate in houses doesn't necessarily correspond to the weather conditions. To improve the situation and increase efficiency a predictive control system can be installed, which calculates a forward-looking load profile. With the newly gained information the system is able to set up and maintain the optimal temperature in the building. Given this information on the predicted energy requirements, the energy supplier can respond and the energy can be generated at the time when it is economically best, as well as maintaining the highest possible efficiency. At all times the energy supply system tries to use as much electricity from renewable energy sources as is possible. Even the discharge of heat and cold energy will be adapted to the external loads.

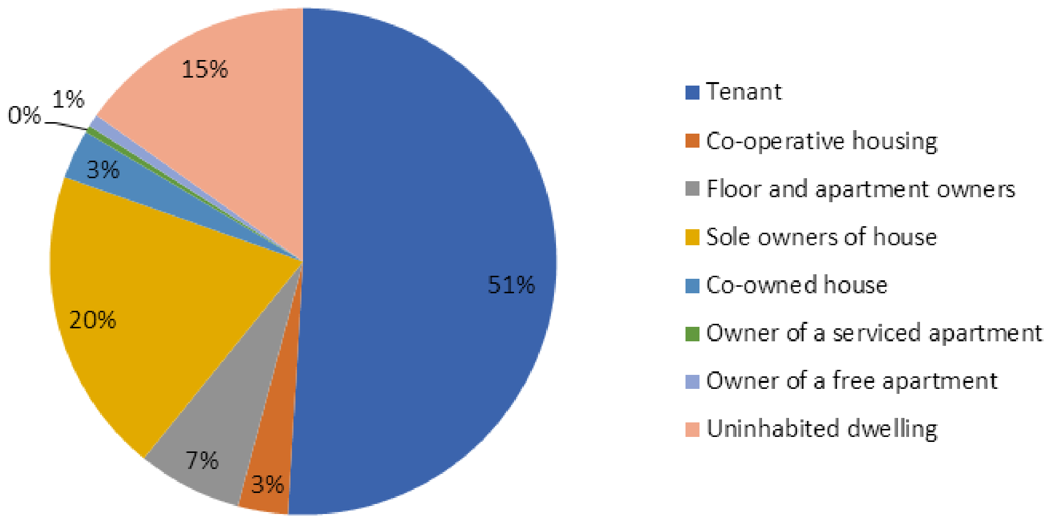
2.2 Swiss Housing Stock Characteristics

Type of dwelling and building ownership

Switzerland's building stock consists of approximately 1.7 million dwellings [2].

At the end of 2011, 36.8 % of Swiss households live in apartments. Since 1970, the apartment ownership rate has steadily risen and the number of apartments in buildings has increased. However, households who own the building in which their apartment is located still make up the majority of owner-occupied apartments.

Figure 13 – Swiss dwelling stock by resident types 2012. Data from [13].



The dominant residential building in Switzerland is the family house. The majority of the buildings with residential use are used only for residential purposes with no other functions. Three-fifths of these purely residential buildings are in urban areas. Single-family homes account for more than half (57 %) of all residential buildings. In rural areas, the proportion of singlefamily homes is slightly higher (59 %) than in urban areas (57 %). Multi-family houses represent a quarter of all residential buildings (26 %), and slightly more than two-thirds (67 %) of all multi-family houses are located in urban areas [10].

Figure 14 – Swiss dwelling stock 2012 by type. Adapted from [10].

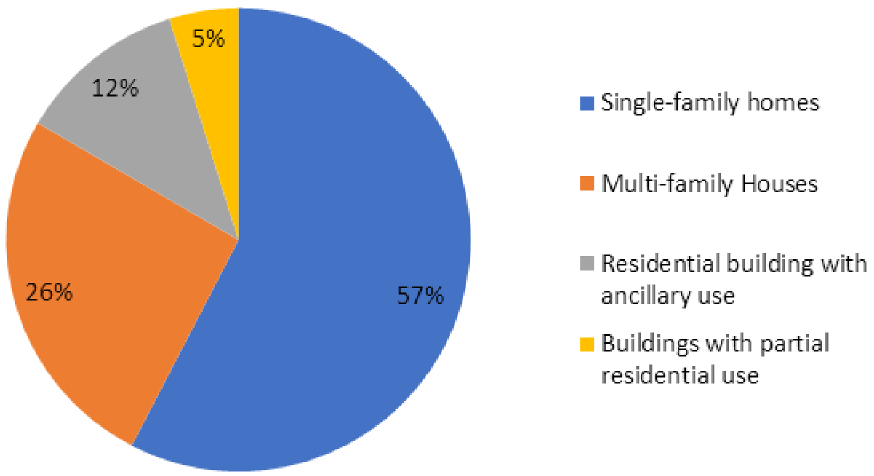
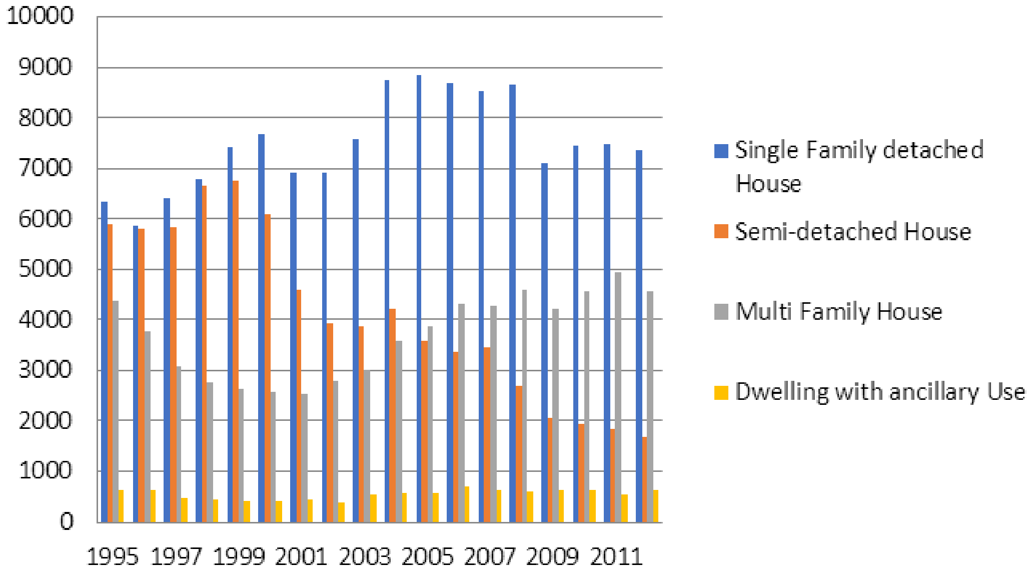


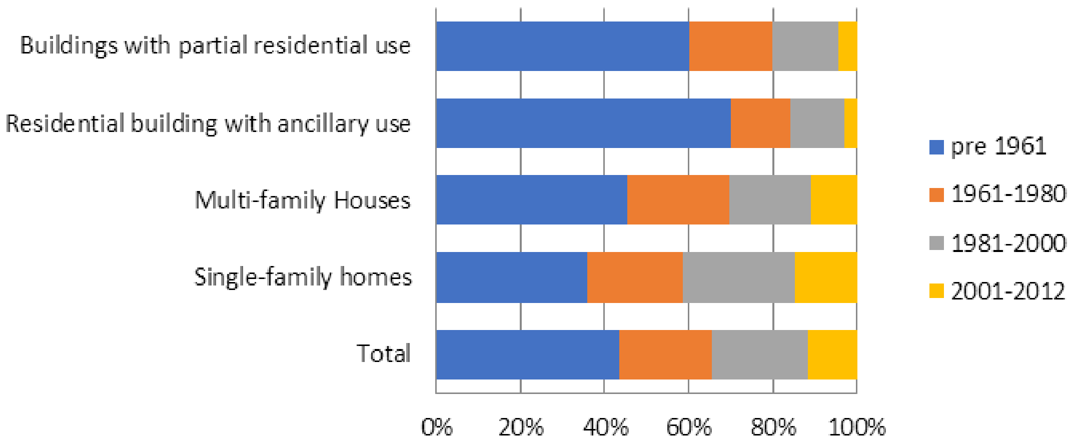
Figure 15 – Newly built homes by type and age. Adapted from [10].



2.2.1 Age of the building stock

Slightly less than half (44 %) of all homes in Switzerland were built before 1961 and thus they are relatively old. The proportion of over 50 year-old single-family homes is just 36 %, so therefore other categories of buildings have higher proportions of old buildings. Buildings that were built in the last 30 years (after 1980) account for a third (34 %) of the total building stock. 41 % of single-family homes have been built since 1980 (higher than the average) whereas multi-family houses at 30 % and other building categories (17 %) are less likely to have been built since 1980. Thus, there are more recently-built single-family houses while buildings for mixed use or multiple families are generally older [10].

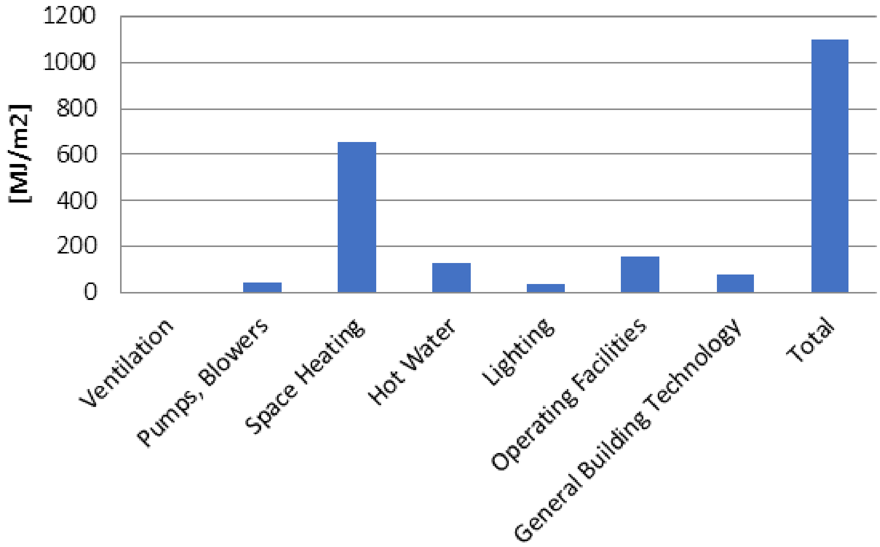
Figure 16 – Swiss dwelling stock 2012 by age. Adapted from [10].



Heat demand

As mentioned previously, the energy demand for dwellings is dominated by space heating followed by the operation of facilities and hot water.

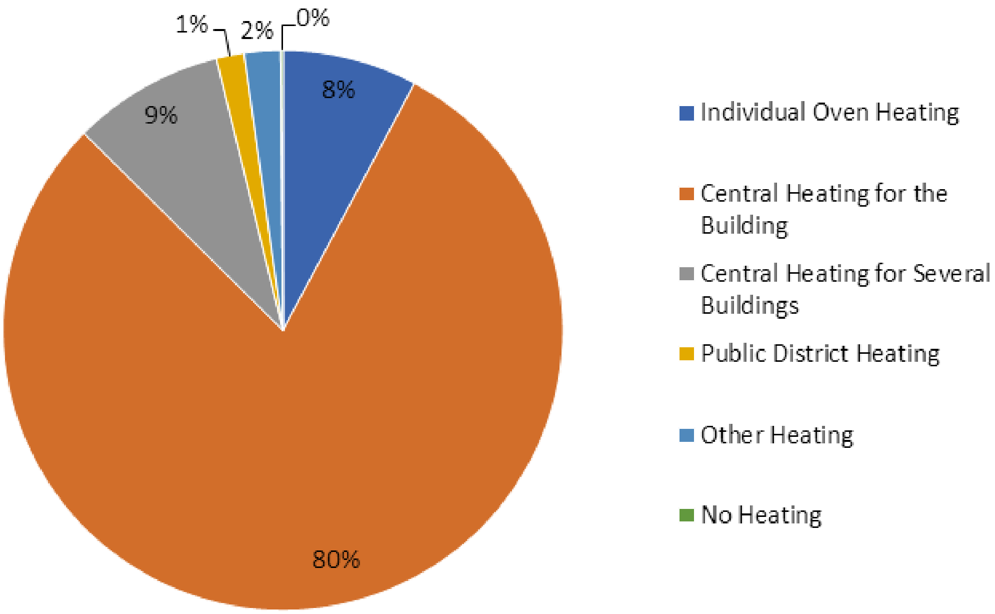
Figure 17 – Energy demand for a singlefamily house 2012. Adapted from [10].



Heating system type and fuel type

The vast majority (87 %) of all buildings, whether multi-family or single-family houses, use a central heating system. In some Swiss cities, for example in Basel, the central heating systems are replaced by district heating networks. Generally, in urban areas central heating is the dominant system, while in rural areas there are a greater percentage of more traditional systems such as the single oven and floor heating. One in every ten buildings in Switzerland heat supply is by single oven- or floor heating [10].

Figure 18 – Heating systems of Swiss housing stock 2012. Adapted from [10].



2.2.2 Building stock by fuel type for space heating

Heating oil is by far the most important energy source for Swiss residential heating, with almost half of the buildings heated with oil. 15 % of buildings have gas heating and about one tenth are heated with wood (12 %) or electricity (10 %). In the buildings heated with the traditional single oven wood is used most often as fuel. Only a fifth of these buildings are also heated with electricity and 16 % have additional heating using fuel oil. In both urban and rural areas, heating oil is the most used energy source (52 % and 47 % respectively). In the urban areas gas (22 %) and electricity (8 %) are the main fuel sources used in addition to the heating oil. In the rural areas mainly wood (22 %) and electricity (13 %) are used alongside heating oil. The stock of buildings with a heat pump has doubled since the beginning of the 21st century [10].

Figure 19 – Energy source for space heating in a singlefamily house 2012. Adapted from [10].

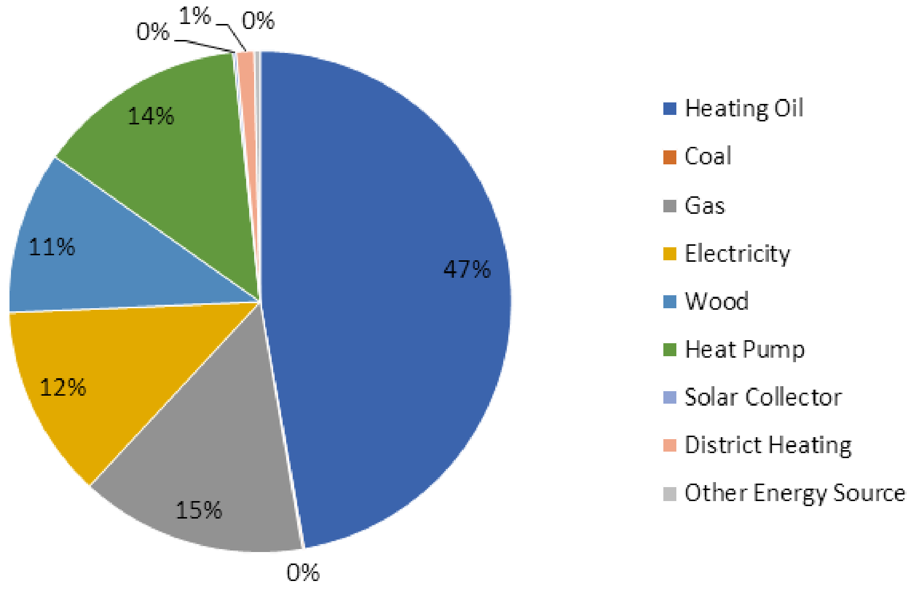
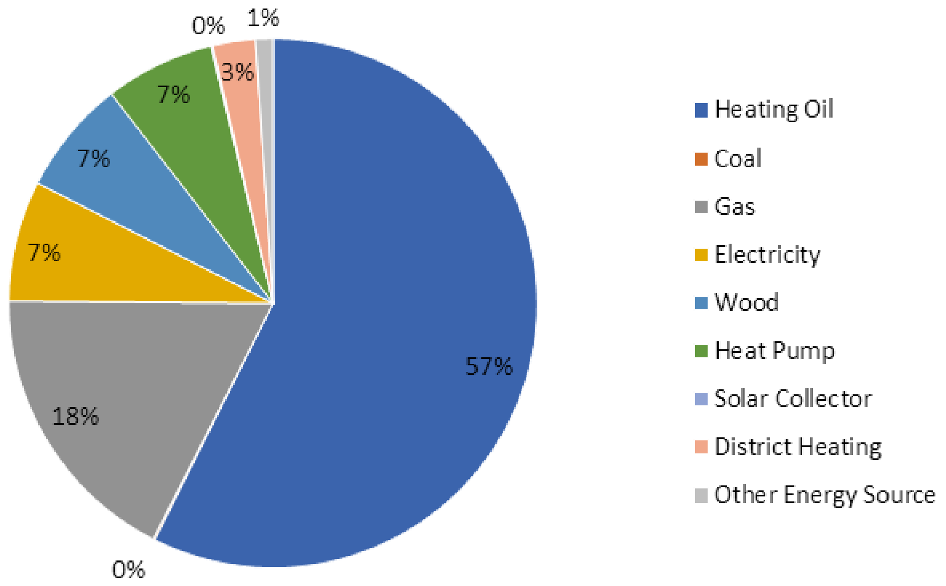


Figure 20 – Energy source for space heating in a multifamily house 2012. Adapted from [10].



2.2.3 Building stock by energy type for hot water heating

Currently the two most important sources of energy for domestic hot water heating are electricity and fuel oil. While in single-family houses electricity is the dominant energy source for water heating, oil is preferred in multi-family homes. Water heating using a heat pump is in place in Switzerland, but hasn't been established yet as a popular alternative.

Figure 21 – Energy source for water heating in a singlefamily house 2012. Adapted from [10].

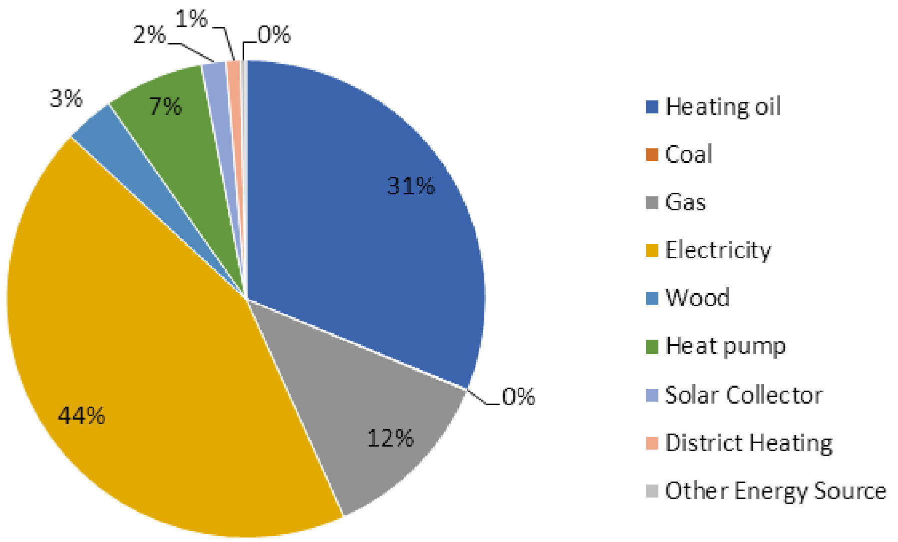
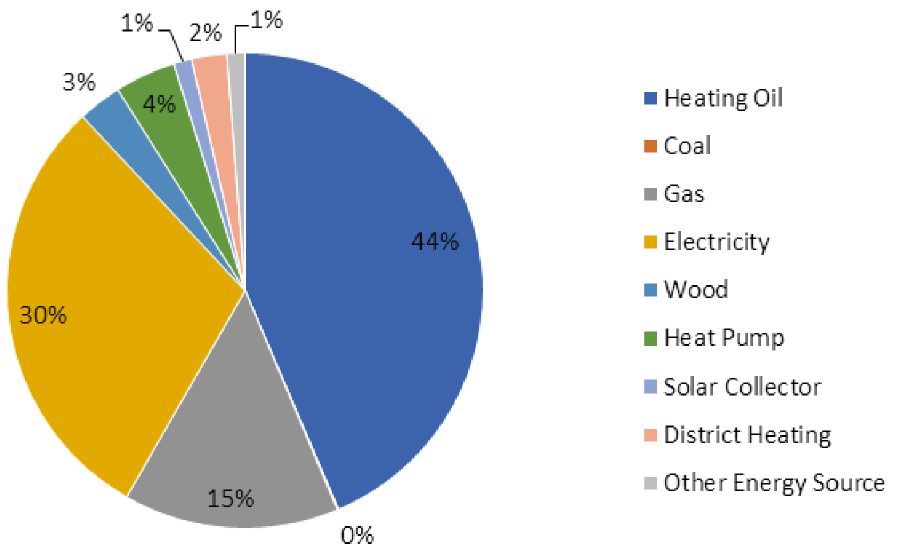


Figure 22 – Energy source for water heating in a multifamily house 2012. Adapted from [10].



Use of storage tanks

Many hot water heating systems in Switzerland use storage tanks because the unmodulated thermal energy producers switch on and off constantly. There are also a percentage of households using hot water storage tanks to store the excess thermal energy from log-wood heating systems, such as the single oven which is popular in rural areas.

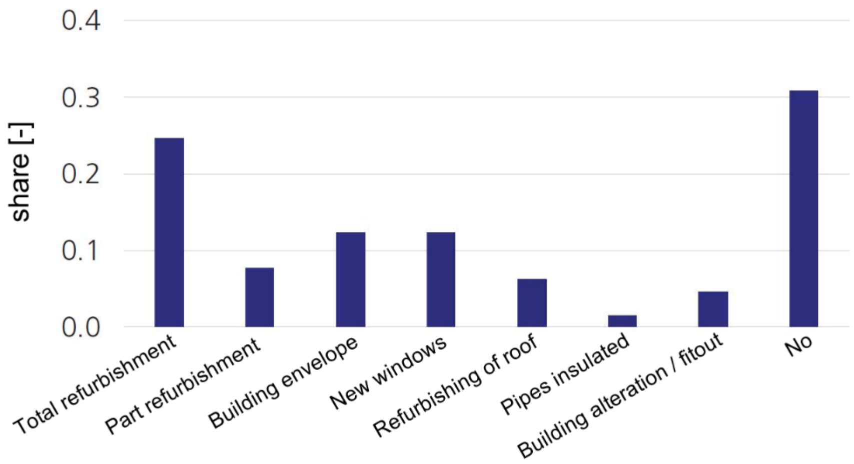
Hot water is also sometimes centrally produced, and then fed into a decentralized hot water system that supplies two or more draw-off points from the water heating system. This method of water heating is no longer permitted (MuKEn) and a new law allows decentralized water preparation with direct electric heating only in special cases.

In new buildings legislation sets a maximum amount of 80 % of heating demand that can be covered with non-renewable energy. The central water purification system supplies all hot water draw-off points of a building or group of buildings. Thermal storage can be added as a separated storage system or integrated in the storage from the building's heating system, if it is a central heating system.

2.2.4 Renovation of dwellings (field analysis)

These data come from a field analysis of heat pump systems. In the refurbished buildings discussed, it is important to note that half of them were built after 1970 and 70 % more energy-relevant refurbishment measures were taken. In 25 % of the buildings a total renovation was made before the heat pump was installed.

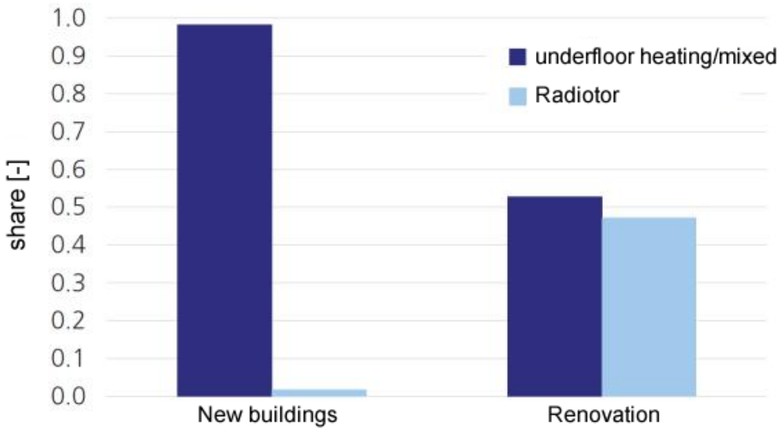
Figure 23 – Type of renovation of the field analysis. Adapted from [9].



2.2.5 Heat distribution system (field analysis)

This field analysis shows that 92 % of new buildings use under-floor heating, in some cases supplemented by radiators. In renovated buildings, the amount of floor heating is 53 % and far more radiators are used to heat the space [9].

Figure 24 – Distribution system of the field analysis. Adapted from [9].

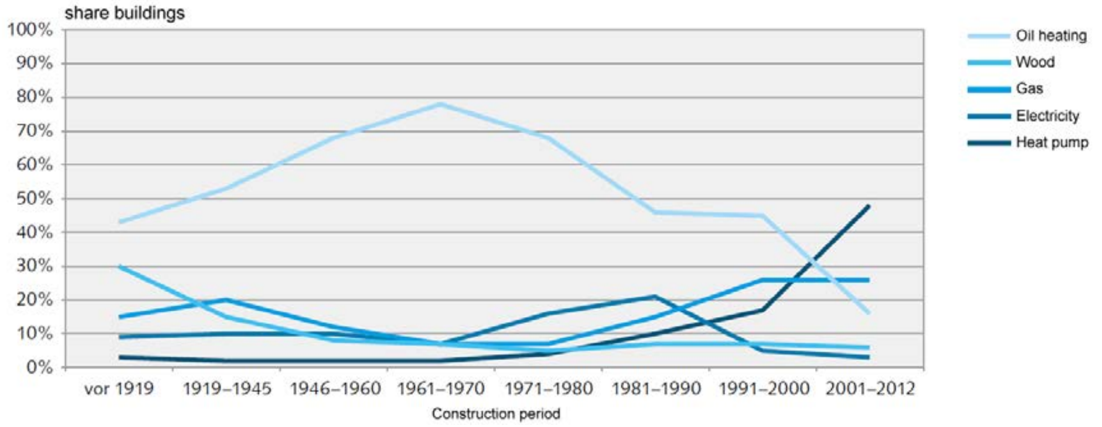


2.3 Trends in the heating market

Heating systems types

In Switzerland since 1995 the trend in heating systems in the market is clearly towards the heat pump. In contrast, the use of fuel oil has dropped and use of gas and wood has remained unchanged since 1995, while the choice of solely electric heating has fallen steadily since 1985. Figure 14 shows that the primary energy requirements will decrease throughout, since the biggest influence on energy demand is space heating.

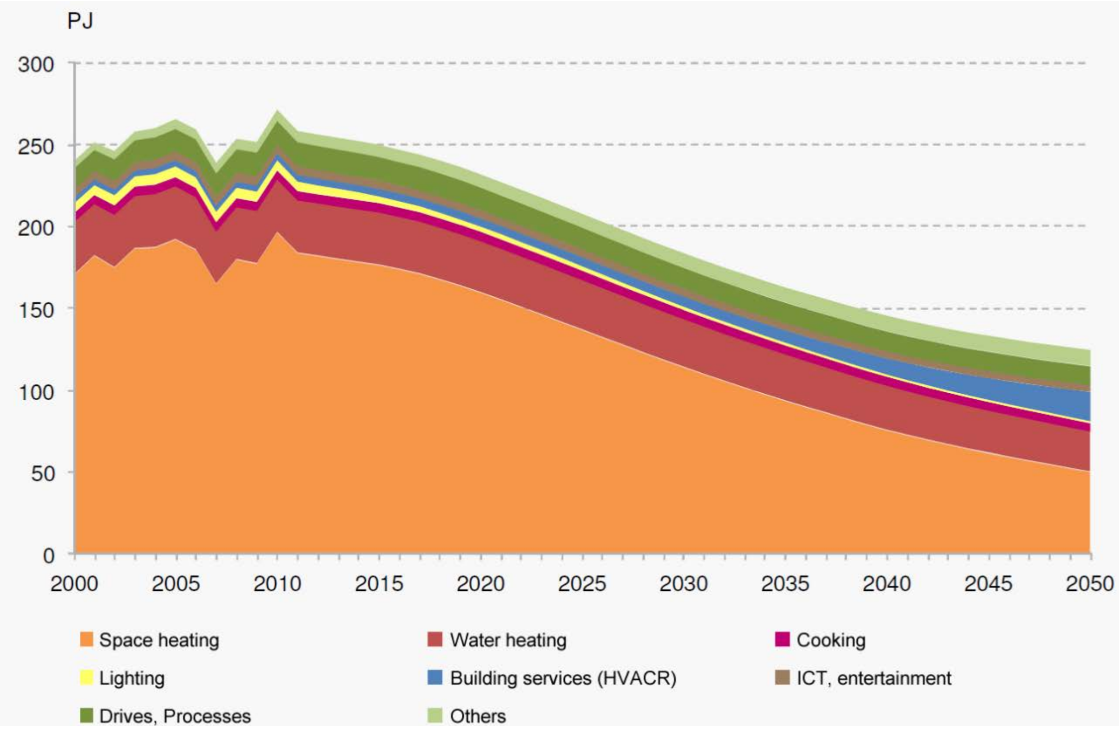
Figure 25 – The five most important energy sources for heating by period of construction. Adapted from [10].



Fuel types

The proportion of space heating as an element of overall energy demand is decreased by improving efficiency. With a share of almost 53 % space heating is quantitatively the most important use. The size increase shows up in climate, ventilation and building services, hot water and other consumption.

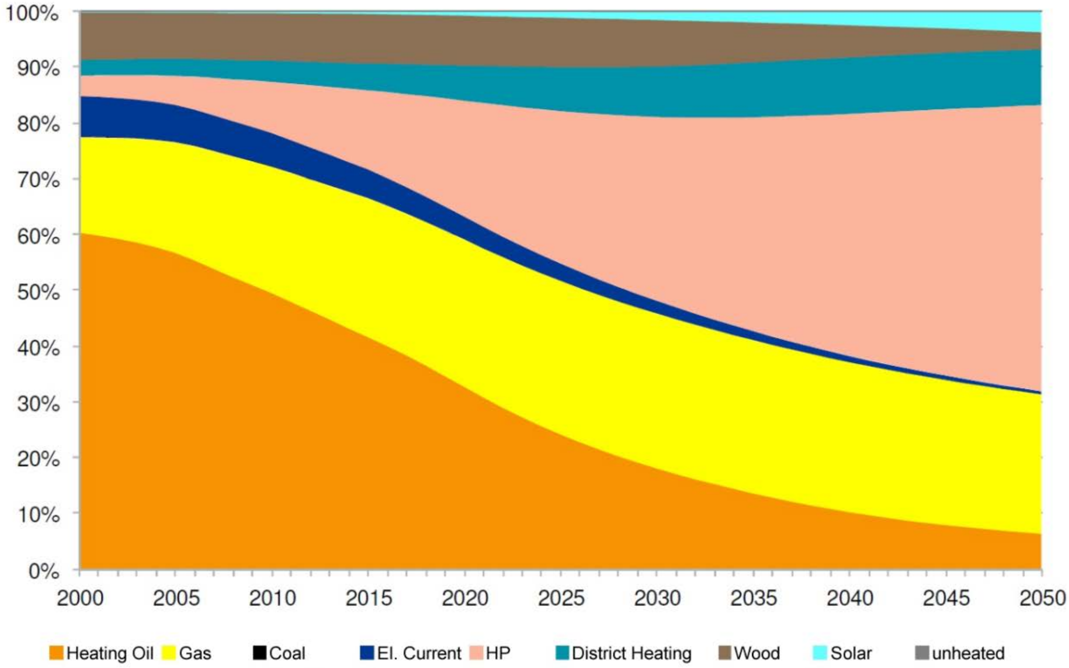
Figure 26 – Scenario "New energy policy", private households: final energy demand by purpose from 2000 – 2050 in PJ. Adapted from [4].



Heating structure of the living space

In the future, heating oil will be replaced by heat pumps and district heating to heat Swiss households.

Figure 27 – Scenario "New energy policy", private households: heating structure of the area population 2000 – 2050 in %. Adapted from [4].



Starting in 2020 with new multi-family houses the passive house standard will be a specific heat requirement of about 10 watts per square meter EBF (energy-related surface), which will achieve an energy demand of 15 kWh per square meter each year. By 2025 all new multi- and single-family homes will comply with this standard. After 2025 the annual demand for new buildings will decrease to zero. In 2050 the specific energy demand will be around 6 watts per square meter for multi-family houses and also for single- or double-family homes.

Table 4 – Scenario "New energy policy", private households: development of specific heat capacity requirements for new buildings and renovations; in W / m^2 EBF. Adapted from [4].

	2000	2010	2020	2030	2035	2040	2050
New Building							
Single- and double-family home	57.6	32.3	17.1	8.7	8.5	8.3	8.1
Multi-family home/NWG	40.8	21.1	9.5	6.8	6.6	6.5	6.3
Renovation							
Single- and double-family home	60.3	48.4	27.3	13.0	12.7	12.5	12.1
Multi-family home/NWG	44.5	30.6	15.3	10.2	9.9	9.7	9.4

Figure 28 and Figure 29 show the planned final Swiss energy consumption in PJ for space heating and hot water. For the generation of space heating it is expected that the primary source of energy will be ambient heat harnessed through heat pump systems. Similarly, the future production of hot water is planned to come mostly from solar power and ambient heat pumps. Generally for both heating systems, a significant reduction of fuel oil is desired.

Figure 28 – Scenario "New energy policy", private households: final energy consumption for space heating 2000 – 2050 by energy sources in PJ. Adapted from [4].

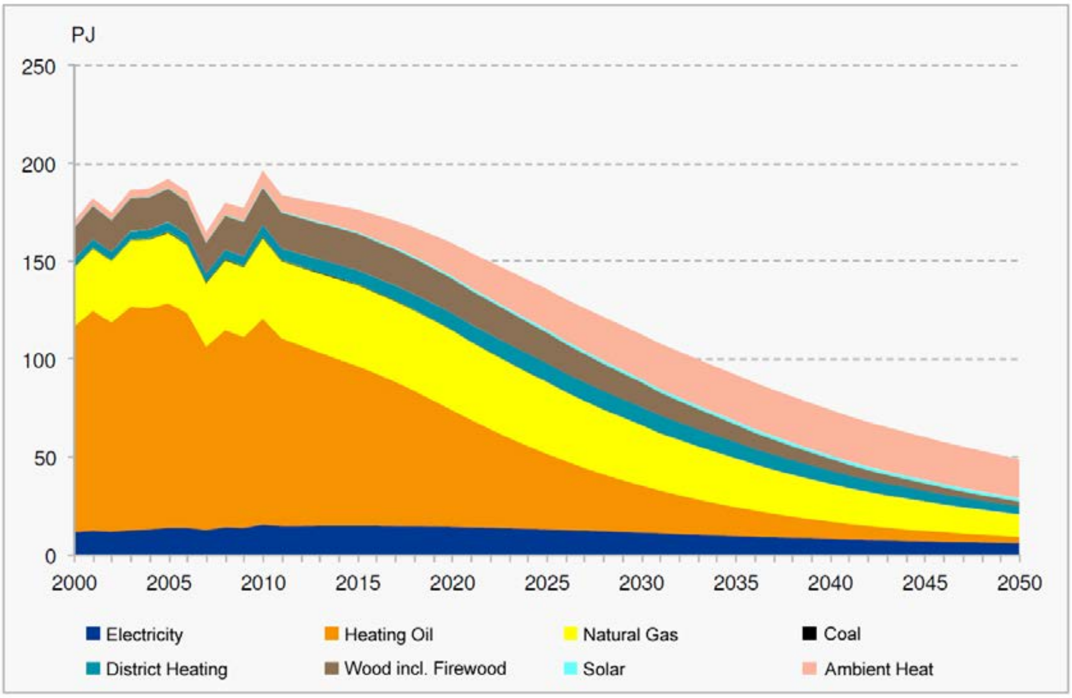
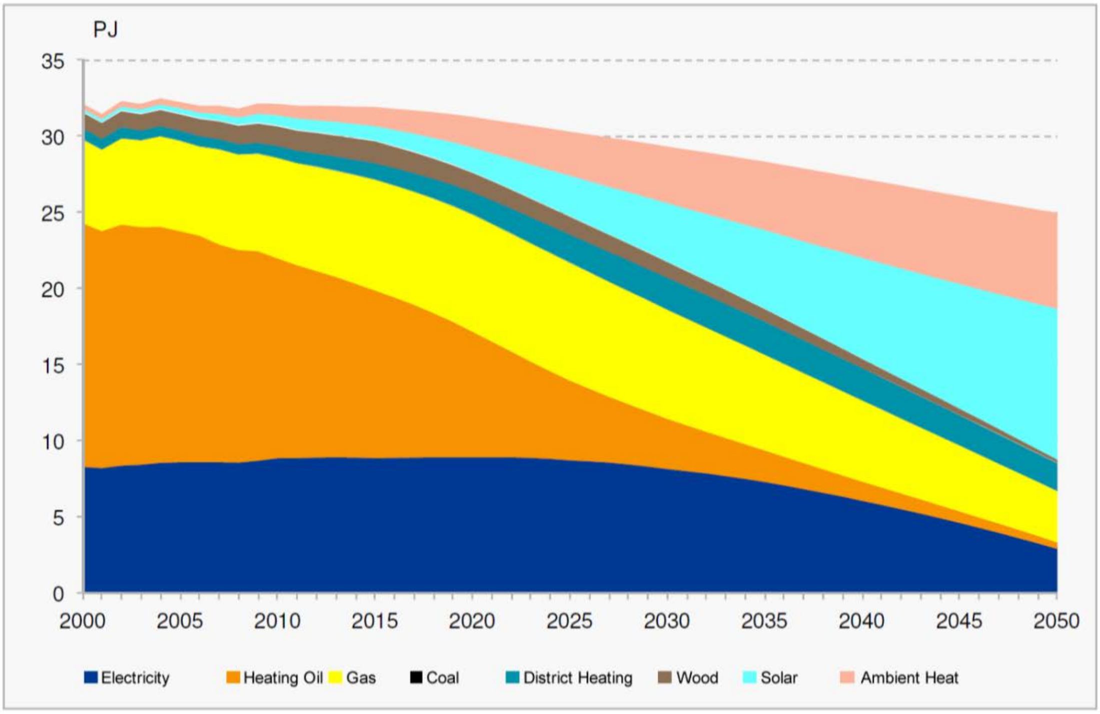


Figure 29 – Scenario "New energy policy", private households: final energy consumption for producing hot water 2000-2050 by energy sources, in PJ. Adapted from [4].



2.4 Customer preferences

The control of the heating system depends on which kind of heating system is installed. A heat pump system enables the consumer to control the power or temperature level in the home. The heat generation of a wood-fired heating system cannot be controlled, and therefore thermal storage must be added, to store part of the energy and release it over a longer time.

The flow temperature and the return temperature of the heating system adapts to the outside temperature and regulates the output in response. With radiator-based central heating systems, thermostats on the radiators in all rooms mean the temperature can be fixed at an appropriate level. Most radiator thermostats simply regulate the flow of heated water through them, depending on the temperature in the room. There are also smart radiator thermostats which can be controlled from an external central system. In most buildings, the room temperature can be reduced during the night to save energy.

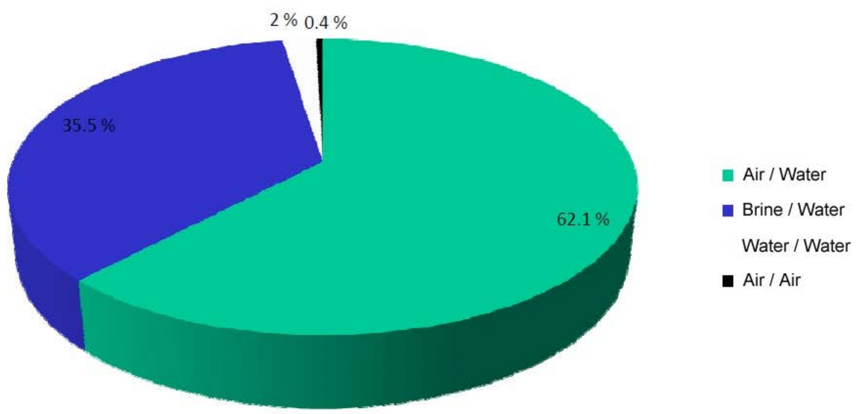
3 Analysis of the Swiss domestic heat pump market

3.1 Installed heat pump capacity

Technology: a/w, w/w, b/w, dx/w, a/a, GAHP

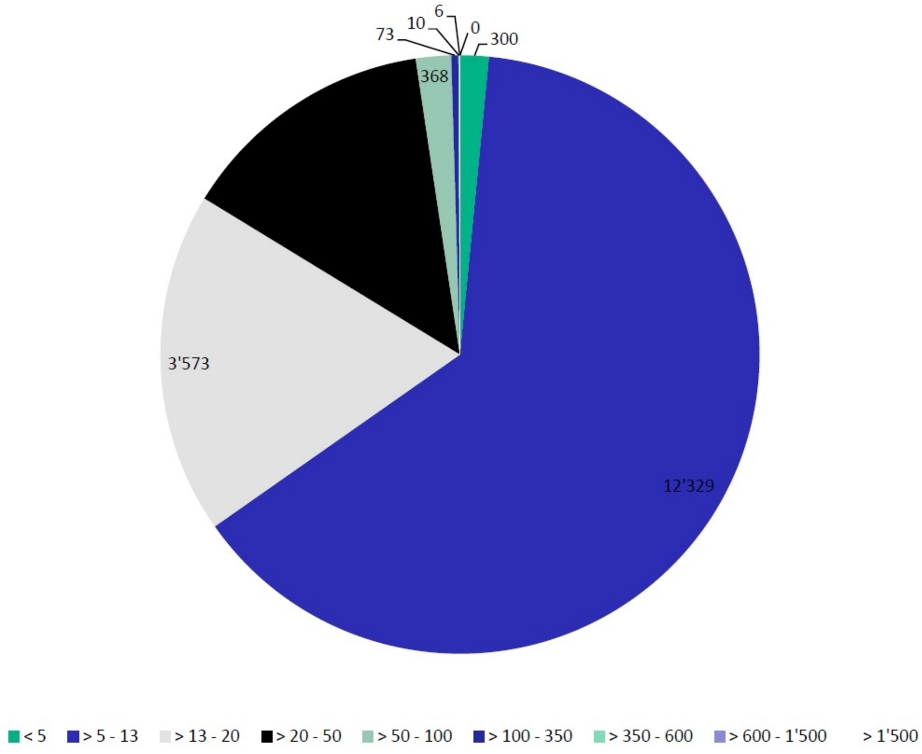
Heat pumps are used in Switzerland in tens of thousands of applications. There is a high percentage and also a strong growth of using heat pumps to heat buildings (especially in smaller residential buildings). Currently there are more than 200,000 systems operating in Switzerland. A strong additional increase of an average of 20,000 units per year has taken place in the last 5 years. Basically, heat pumps in Switzerland are of high quality and efficiency. With approximately 62.1 % usage, air / water heat pumps are the most used ones, followed by brine / water heat pumps with about 35.5 %. The remaining 2.4 % are water / water (2 %) and air / air (0.4 %) heat pumps [7].

Figure 30 – Proportions of the type of installed heat pumps in Switzerland [7].



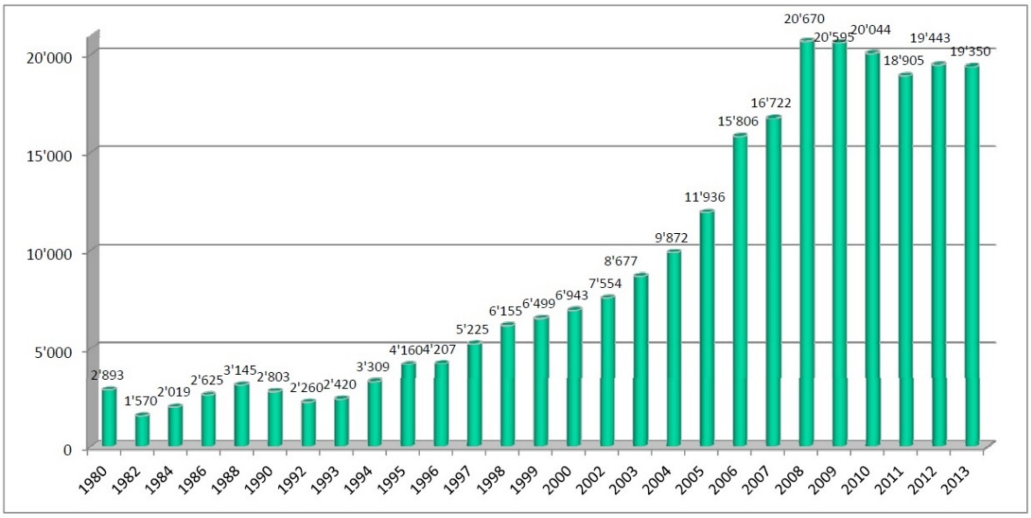
Heating capacity segmentation

Figure 31 – Number of installed heat pumps by power (kW) in 2013 [7].



3.2 Trends in the heat pump market

Figure 32 – Number of installed heat pumps (1980 – 2013) [7].



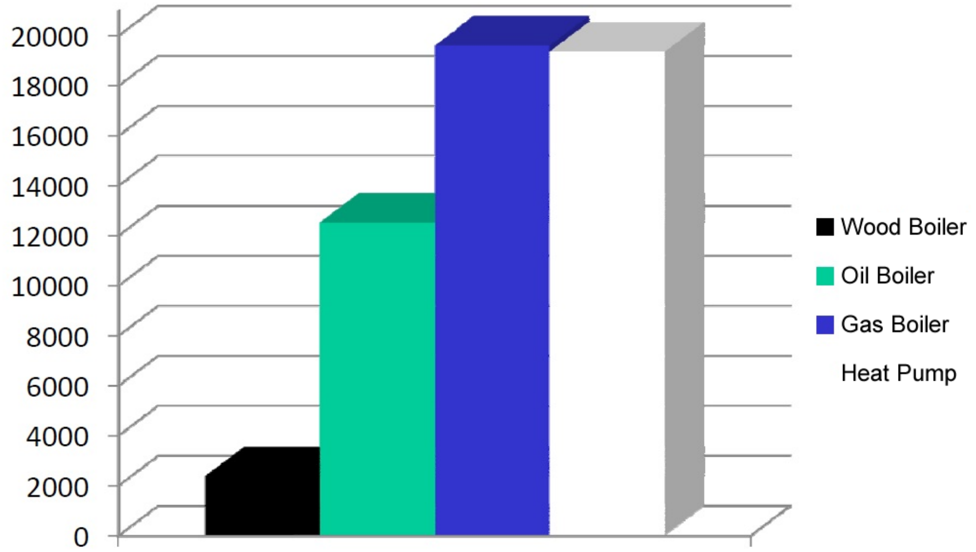
The trends in the use of heat pumps are affected by: the price of energy (electricity, oil and gas); ecological sensibilities; and also political influences such as legislation. Since 2008 the sales of heat pumps have remained stable at 20 thousand units per year. This stagnation of sales can be traced back to achieving market saturation in new buildings being constructed. On the other hand, there is no indication of saturation approaching in the renovation of old buildings.

So, there are three possibilities for development in the heat pump market: renovation, installation of a heat pump system, or installation of a water-water system without renovation. In the case of the construction of systems, the trend is moving towards split-systems. The split-system is more favourable and space-saving, and further, these systems often integrate the heating system for the house and the domestic water heating system [15].

Displaced heating system type

The figure shows the heating systems sold in Switzerland. As the figures indicate, oil boilers still have a relevant share of the heating system market, while the number of gas boilers sold is similar to the number of heat pumps.

Figure 33 – Heating systems sold in 2013 [7].



3.3 Market drivers

Ecological awareness and also government regulations have had, and will continue to have, a positive influence on the heat pump market. A decisive regulation in this field is the Ordinance on Air Pollution Control (OAPC, LRV Luftreinhalte-Verordnung) from 1985. This Ordinance is intended to protect human beings, animals and plants, their biological communities and habitats, and the soil against harmful effects or nuisances caused by air pollution.

Another program, the “Climate Cent (Klimarappe)” from the year 2005, includes but is not limited to, promoting energy-conserving renovation of cladding on building envelopes, adding a surcharge on fossil fuels and encouraging the reduction of CO_2 output.

As a result of the “Energiewende” the Energy Strategy 2050 was developed and decided. This strategy aims to:

- increase the renovation rate for old buildings,
- create incentives to replace fossil- and electric-fueled heaters,
- increase aid for conversion to renewable energy in the redevelopment area.

On the other hand, energy research is an important pillar. So far, the federal government has set aside 200 million francs a year for research. In the context of the Energy Strategy 2050 additional funds for energy research (CHF 202 million for the period 2013 -2016) and for pilot, demonstration and flagship projects of the BFE (an increase from the previous 5 to 35 million Swiss francs per year until 2015) are available.

The development of technology also has a positive aspect of heat pump sales until now and also in future. Thereby the COP (Coefficient of performance) and the SPF (Seasonal Performance Factor) play a decisive role. There is a demand in summer to cool houses, which further supports the sale of heat pumps and there are products on the market to fit the function of cooling in summer and heating in winter [15].

3.4 Market barriers

In the case of house renovation there isn’t only the financial investment in a heat pump, there are additional costs for the planning and the disposal of the old heating system. Just as important as the installation of heat pumps is the renovation of the house's insulation, which needs to be completed first. These additional costs on top of the expected investment in a renovation are a financial block to the homeowner in deciding whether to install a heat pump.

Another barrier is created by the planning companies. Because of the complicated planning process of renovation and the installation of a new heating system, they advise their customers against choosing heat pumps. Indeed, some companies don’t even mention the possibility of basing a system on a heat pump.

Bad experiences with appliances and systems have also had a negative impact on the heat pump market. One problem is the lack of skilled manpower. Therefore, a lot of work, like installation or repair of system, has to be done by non-specialist workers from other branches of the construction industry, which can reduce the quality of the installation. [15].

A List of smart heat pump projects in Switzerland

A.1 D-A-CH Smart Grid

To complement the existing international activities of Switzerland in the field of "Smart Grids", the "Memorandum of Understanding" (MoU) was signed on November 27, 2009, which should enforce cooperation between Germany, Austria and Switzerland in the field of research and development of ICT-based (ICT: Information and Communication Technology) energy systems.
Through the MoU, the three member countries should work together closely in the prospective promotion of ICT research and development. Thereby ICT products, procedures and development services for a sustainable and long-term stable electricity supply should be ensured.
The scope of cooperation includes the exchange of information and knowledge sharing and coordination of the funding policy measures. The D-A-CH cooperation provides the opportunity to initiate, fund and carry out concrete joint projects. A similar research project between Austria and Switzerland has already been started. In the context of the European Industrial Initiatives of the SET-plan, specifically in the area of "Networks" and "Smart Cities", the D-A-CH cooperation is becoming increasingly important.

A.2 Efficient air/water heat pumps with continuous capacity control

During preceding Swiss Federal Office of Energy research projects “optimisation of fin tube evaporators by reduction of ice and frost formation” and “exergy analysis for increasing the efficiency of air/water heat pumps” valuable findings concerning the increase in efficiency of air/water heat pumps were gained. These findings are now to be implemented in a practical and realistic manner. The aim is to develop universally valid design and planning criteria (“guidance”) for the realisation of efficient, reliable and economic air/water heat pumps with continuous capacity control. The main measure to improve the efficiency of air/water heat pumps is to continuously adapt the generated heating capacity to the heat demand of the building. This study will give an incentive for further development in that area as well as the increase of efficiency of air/water heat pumps, both by heat pump and component manufacturers and also by designers of building services engineering.
An optimised process control strategy depending on the applied control principle of the heat pump has been developed, using simulations as well as experiments. To verify the theoretical findings as well as to investigate different control strategies, three different heat pump prototypes with capacity control and a test facility for air/water heat pumps have been realised. The investigations show that the optimal control strategy and the efficiency of the capacity controlled heat pump strongly depend upon the partial load efficiencies of the compressor and the fan. The experimental investigations have proved the great potential of the capacity control. By using the capacity control the seasonal performance can be increased by approximately 20–50% compared to air/water heat pumps with on/off control. This means the seasonal performance factors can be just as high as the values of brine/water heat pumps with on/off control [16].

A.3 Development of an optimum unit of heat pump and thermal energy storage

The integration of a large amount of new renewable energy sources in the course of the “Energiewende” is an ambitious target. To operate an energy-generation system with a lot of wind- and solar energy requires additional flexibility, as the time discrepancy between production and consumption makes it necessary to upgrade the grids and storage solutions.
An interesting option is the connection of thermal storages. These are already available in great numbers such as hot water heaters and the house's mass being used as a thermal store. The production of heat (room- and process heat as well as hot water) accounts for more than 50 % of the national energy consumption. Local charge management enables the optimal use of the capacity from thermal storage, and in addition to the compensation of fluctuation from new renewable energy sources it makes possible cost reductions for the upgrading of the grid.

Already today’s situation allows for offering the flexibility of thermal storage in the sector. The provision of operating reserve is a possible option. A way to define the value of the flexibility is the revenue opportunities of the sector. Besides determining the revenue opportunities, there are also the costs for the infrastructure (communication, monitoring and control) as well as the operating expense to define.

The WARMup project evaluates the economic efficiency of real scenarios. The focus is on large consumers. In the centre is a high level smart system as a connection between the sector and the flexible charge.

In the first period within the scope of this project a simulator is to be created to show the optimal management of thermal storages. The simulator decides the participation of each sector for every point in time and each different offer. This brings different thermal charges and sectors to model it close to the reality and the corresponding mathematic optimizations formulated [17].

B Analysis of smart-ready products

B.1 The criteria for 'Smart-Ready': analysis of full range of "Smart" capabilities

We assess all the ways in which a heat pump can be "smart", through analysis of several layers of functionality that could be defined as 'smart-ready'. We will give an indication, for each criterion; of its importance for peak shifting (this importance to peak shifting could be seen as a measure of "smartness").

Criteria		*Importance for peak shifting*	*Maturity*	*Future evolution*
Heat pump functionality	Inverter-driven compressor which can ramp down rather than switch off	High[1]	Growth stage[2]	Hopefully to become mainstream technology
	On/off	High	Mature	Mainstream
Control strategies: building thermal mass & storage	Pre-heat algorithms	Low	Low	Some potential[4]
	'Learning' building thermal response	Medium/High depending on building[5]	Growth stage[6]	Promising[5]
	Optimising integration with storage	High	Medium[3]	Promising
Control strategies: outside environment	Weather compensation & variable capacity	Low	Mature[7]	Mainstream
	Responding to weather forecast data	Medium/High[8]	Growth stage	Niche
Control strategies: energy price	Responding to dynamic price signals	High	Low[9]	Depending on the electricity market
	Responding to pre-set price (& CO_2 signals?)	Medium	Low[11]	Depending on the electricity market
Communication capability	2-way communication	High[10]	Mature	Mature
	1-way communication	High	Mature	Mature
Speed of response to communication signal	Dynamic response (minutes)	High	Low	2-way communication required
	Needs advanced notice (hours/days)	Medium[13]	Mature[14]	Mature
Thermal storage	Sensible heat storage (water tanks)	High[12]	Growth stage	Mainstream
	Advanced heat storage technologies e.g. phase-change materials	High[12]	Growth stage	Promising
Integration with 2nd energy source	bivalent system with set-point control to switch from HP to other source	Medium/High	Medium[12]	Some potential[16]

Criteria		Importance for peak shifting	Maturity	Future evolution
	hybrid which switch between heat sources according to price, CO_2	Medium/High	Low	Some potential[16]
	Sophisticated control hybrid which can switch between sources in response to dynamic tariffs	Medium/High	Low	Some potential[16]

(1) When properly regulated, inverter driven HPs are considerably more valuable in Smart Grids than HPs with On/Off regulation because of their increased controllability.
(2) The first high-efficiency appliances are available in the market.
(3) Latent heat storage units still require significant development work.
(4) Typical buildings in Switzerland exhibit a relatively high thermal inertia (floor heating, concrete constructions) which decreases the potential of a quick response system based on room occupation.
(5) Buildings with high thermal inertia exhibit a high potential- For example, if a period of cold weather is expected the thermal mass can be "loaded" in advance. The potential is limited in cases of buildings with low thermal inertia.
(6) Projects are currently running in Switzerland.
(7) Control based on heating curves.
(8) Big thermal storage units present a high potential. Buildings with "low thermal mass" a lower potential.
(9) There is no dynamic electricity pricing in Switzerland.
(10) Necessary especially for HPs with power control.
(11) (If High & Low Tariffs are also taken into consideration then the system is mature)
(12) Subject of current investigations.
(13) Depending on the system and the building a "Registration" in advance can make sense.
(14) Analogous to utility locks.
(15) Typical systems are HPs in combination with solar collectors.
(16) Bivalent systems are difficult to realise from an economic perspective.
(17) If the thermal inertia of the building allows it.

B.2 Defining the Minimum Capabilities for Smart-Ready Heat Pump Systems

The minimum capabilities for smart-ready heat pump systems can be summarized as follows:

- HPs with inverter driven compressors.
- Optimised systems with integrated storages (sensible & PCM).
- Optimised usage of the thermal inertia of the buildings[17].
- Respond to dynamic price signals.
- Communication capability for 2-way communication.
- Communication signal with dynamic response.

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Heat Pump Centre
c/o RISE - Research Institutes of Sweden
PO Box 857
SE-501 15 BORÅS
Sweden
Tel: +46 10 516 5512
E-mail: hpc@heatpumpcentre.org

www.heatpumpingtechnologies.org

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