Historical Case Studies of Energy Technology Innovation

CASE STUDY 4: HEAT PUMPS (SWEDEN & SWITZERLAND).

HEAT PUMPS: A COMPARATIVE ASSESSMENT OF INNOVATION AND DIFFUSION POLICIES IN SWEDEN AND SWITZERLAND

Bernadett Kiss
International Institute for Industrial Environmental Economics, Lund University

Lena Neij
International Institute for Industrial Environmental Economics, Lund University

Martin Jakob
TEP Energy GmbH, Zurich

AUTHORS' SUMMARY

The development and introduction of heat pumps provides an interesting illustration of policy influence and effectiveness in relation to energy technology innovation. Heat pumps have been supported by several countries since the 1970s as a strategy to improve energy efficiency, support energy security, reduce environmental degradation, and combat climate change. Sweden and Switzerland have been essential to the development and commercialization of heat pumps in Europe. In both countries, numerous policy incentives have lined the path of technology and market development. Early policy initiatives were poorly coordinated but supported technology development, entrepreneurial experimentation, knowledge development, and the involvement of important actors in networks and organisations. The market collapse in the mid 1980s could have resulted in a total failure - but did not. The research programmes continued in the 1980s, and a new set of stakeholders formed - both publicly and privately funded researchers, authorities, and institutions - and provided an important platform for further development. In the 1990s and 2000s, Sweden and Switzerland introduced more coordinated and strategic policy incentives for the development of heat pumps. The approaches were flexible and adjusted over time. The policy interventions in both countries supported learning, successful development and diffusion processes, and cost reductions. This assessment of innovation and diffusion policies for heat pump systems can be used to generalise some insights for energy technology innovation policy.

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1 INTRODUCTION

This paper presents the results and the policy programmes being applied to introduce and commercialize heat pumps, focusing on ground source heat pumps for residential space and hot water heating. Heat pumps are of interest since they have been supported by several countries since the 1970s as a strategy to improve energy efficiency, support energy security, reduce environmental degradation and combat climate change (IEA, 2008). Two countries, essential for the development and commercialisation of heat pumps in Europe, are Sweden and Switzerland. Since the early 1970s the number of installed heat pumps in Sweden and Switzerland has been rapidly growing, and as a result these two countries have the highest number of ground source heat pumps per capita and per land area respectively (EGEC, 2009). An important underlying reason may be that the two countries have had energy systems with similar characteristics, particularly a substantial supply of electricity for heating in the 1970s and 1980s. Heat pumps were therefore seen as energy efficiency measures rather than a means of substituting electricity for fossil fuels at the point of use.

Heat pump systems offer an energy efficient solution as they use 'free energy' (the solar energy stored in the earth) to provide heating, cooling, and hot water for homes. A heat pump moves heat from a low temperature heat source (i.e., bedrock, surface soil, water and outdoor air) to a higher temperature heat sink (i.e., the indoor space). Heat pumps are usually characterized by their heat sources (air, water and ground) and/or by the mediums between which they transfer heat (air-to-air, air-to-water, water-to-air, water-to-water). Ground source heat pumps (GSHPs) are a variant of either water-to-air or water-to-water heat pumps. Depending on the available land areas and the soil/rock types, GSHPs can be installed horizontally (soil), vertically (bedrock) or in a pond/lake. The most common heat pumps are motor-driven (electrically-powered or gas-fuelled). The ratio of thermal energy gained to electric power used is called the Coefficient of Performance (COP) and is in the order of 2.5 - 5. So if electrical space heating is replaced by a heat pump, considerable electricity will be saved. If a heat pump replaces an alternative heating system, savings will depend on the configuration of that system, including its conversion efficiency and distribution losses.

2 MARKET DEVELOPMENT OF GROUND SOURCE HEAT PUMPS

2.1 Market growth

The heat pump market took off during the 1980s following the oil crisis in the late 1970s (see Figure 1 and Figure 2). In Sweden, more than 900,000 heat pumps have been sold by Swedish heat pump companies since the early 1980s (SVEP, 2009). As of 2010, approximately 98% of the heat pumps sold serve the residential market, with most of the sales being small heat pumps (<20kW) for single family houses. Reports show that ground source heat pumps add value to properties (Boverket, 2008; Energimyndigheten, 2009). Until the mid 2000s, ground source heat pumps dominated market sales, constituting on average 45% of heat pumps sold each year with annual growth rates between 1993 and 2006 exceeding 30% (SVEP, 2009). Since 2000, the market share of air-to-air heat pumps has increased rapidly, and in 2008 air-to-air heat pumps consisted of more than 60% of total sales (see Figure 1). Exports have also represented a significant share of sales. According to interviews with manufacturers, in the mid 2000s approximately 40-50% of total Swedish production was exported.

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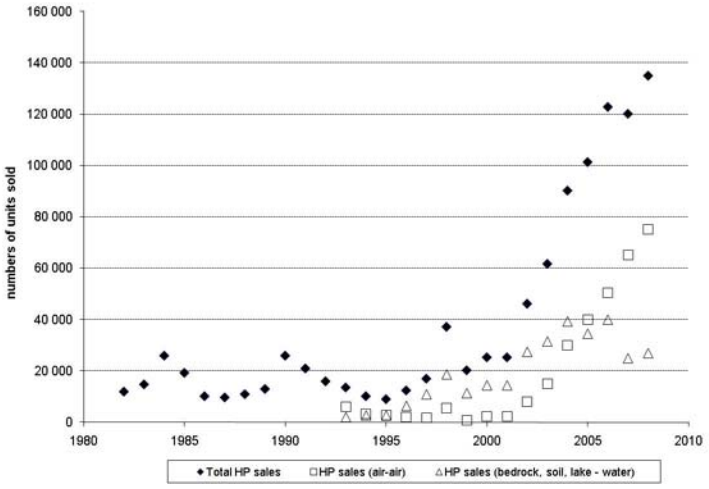

FIGURE 1. ANNUAL SALES STATISTICS OF HEAT PUMPS IN SWEDEN, 1980 – 2008, BASED ON DATA FROM THE SWEDISH HEAT PUMP ASSOCIATION (SVEP, 2007; NOWACKI, 2007)**.** NOTES: HP = HEAT PUMPS. GROUND SOURCE HEAT PUMPS (INSTALLED IN SINGLE FAMILY HOUSES) PROVIDED 3.9% OF THE TOTAL DEMAND FOR SPACE AND WATER HEATING IN 1990. THIS HAD RISEN TO AROUND 10% OF TOTAL DEMAND IN 2008 (ENERGIMYNDIGHETEN, 2008; NOWACKI, 2007).

In Switzerland, more than 180,000 heat pump units have been sold since the 1980s (FWS, 2009). Most of the sales have been small heat pumps (<20kW) predominantly installed in new single family houses. The sales of ground source heat pumps increased rapidly in the 1990s and by the mid 2000s the market share of heat pumps among space heating and domestic hot water heating systems in new homes was around 75% (Rognon, 2006). In 2009, more than 20,500 ground source heat pump systems were sold, which shows an increase of almost 20% per year since 1993 (FWS, 2009).

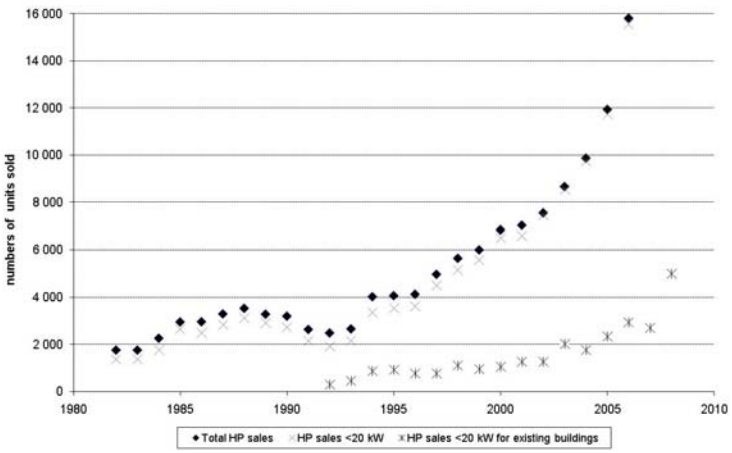

FIGURE 2. ANNUAL SALES STATISTICS OF HEAT PUMPS IN SWITZERLAND, 1982 – 2006 (ALL TYPES OF HEAT PUMPS), BASED ON DATA FROM THE SWISS HEAT PUMP PROMOTION GROUP (FWS, 2009; BASICS, 2002)**.** NOTES: HP = HEAT PUMPS. GROUND SOURCE HEAT PUMPS PROVIDED 2.4% OF THE TOTAL DEMAND FOR SPACE AND WATER HEATING IN 2000 IN THE RESIDENTIAL SECTOR. THIS HAD RISEN TO AROUND 5.4% OF TOTAL DEMAND IN 2008 (BFE, 2010).

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2.2 Policy programmes

2.2.1 Early Support

To support technology and market development, both Sweden and Switzerland introduced broad-ranging policy programmes which emphasized R&D and the development of heat pumps based on available components (see Table 1 and Table 2). In Sweden, R&D programmes were complemented with subsidies, favourable loans, trainings and information campaigns. Long standing Swedish experience in water well drilling also supported the early development of the emerging market as it was applicable to borehole drilling used in the installation of vertical ground source heat pumps. In Switzerland, early support focused on conferences, training and testing activities. The policy incentives attracted many new heat pump manufacturers and installers to the market, and by the early 1980s, the number of heat pump installations increased rapidly. However, in the mid 1980s the price of oil was reduced and in Sweden, government subsidies for domestic heat pumps were terminated. As a result, the demand for heat pumps decreased significantly and the market collapsed in both countries. In 1984 there were about 130 heat pump companies (manufacturers, retailers and installers) in Sweden, most of which were small and working locally. In 1986 only a few companies were left (Florin, 1987; SPK, 1986; Törnell, 2007). Moreover, several types of heat pump installed in the early 1980s were registered as technically malfunctioning (Lindeberg, 1984). To support a more stable market development, new policy instruments were introduced in the early 1990s. The foundation for further trust was based on extended research activities focusing on aspects such as quality improvement, new compressor types, optimization of heat pump systems, the reduction of refrigerant volume, computer simulations as well as replacement of “freons” by HFC and natural refrigerants. These research activities were then complemented with instruments to provide more stable market development.

2.2.2 Renewed support: Sweden

In 1993, Sweden launched a technology procurement programme for ground source heat pumps. The objective of the programme was to stimulate the development and commercialisation of innovative and high quality heat pumps. The programme aimed to bridge the gap between buyers and manufacturers, helping buyers get products better suited for their needs, and helping manufacturers reduce risks associated with developing these products. The technology procurement programme worked from the end-use side. A specification outlining the requirements of advanced heat pumps was developed by a group of dedicated purchasers and specialists in cooperation with Swedish Agency for Economic and Regional Growth (NUTEK). The specification required a heat pump that was 30% more efficient and 30% cheaper than the existing models on the market, met high quality and reliability standards, and did not allow products using CFCs or HCFCs (stratospheric ozone depleting chemicals). A competition was announced in which manufacturers were invited to enter prototypes with features that met the requirements of the specification. The buyers’ group guaranteed that at least 2,000 units would be purchased of the winning model. To ensure credibility, third party testing of the prototypes and the whole heating system was performed. (Initial difficulties in replacing CFCs / HCFCs led to a new research programme being launched in the mid 1990s).

To support a stable market development of improved heat pumps, the procurement programme was combined with additional policy incentives, such as investment subsidies, information campaigns and evaluations. In all, 25% of the procurement budget was earmarked for the evaluation of heat pump

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installations through a test and certification programme (free tests for participants, and certification of the quality and technical performance of the heat pumps). Evaluation results were presented in articles and seminars. A further 50% of the procurement budget was allocated to information activities, including information campaigns, brochures and articles (Miljöstyrningsrådet, 2008). The procurement programme boosted demand for heat pumps with sales doubling between 1995 and 1996. Between 1996 and 2006 the number of installations of bedrock, soil and lake heat pumps increased at an average of 35% per year (SVEP, 2007). The increase in installations of heat pumps in the late 1990s and early 2000s was further supported by additional government subsidy programmes (1998-99, 2001-03 and 2006-10). In 2005, a quality label for heat pumps was introduced (P-label) as well as a standard on the installation of the geothermal system (Normbrunn-97), including requirements for the borehole, equipment, and competence of the drillers which was also assured by a voluntary certification scheme and new certification courses for installers.

TABLE 1. POLICY INSTRUMENTS AND MAJOR EVENTS RELATED TO HEAT PUMP DEVELOPMENT IN SWEDEN, 1974-2008.
NOTES: SEE TABLE FOOTNOTES FOR ACRONYMS. SOURCES: ÅSTRAND ET AL., 2005; NILSSON ET AL., 2005; ENERGIMYNDIGHETEN, 2007B; ENERGIMYNDIGHETEN, 2007A; ENERGIMYNDIGHETEN, 2002B; NEIJ AND ÖFVERHOLM, 2001; ENERGIMYNDIGHETEN, 2002A; SFS1997:635, 1997; NOWACKI, 2007; SVENSSON AND HAVSJÖ, 2006; SVEP, 2007; TÖRNELL, 2007.

PHASE	POLICY INSTRUMENTS AND MAJOR EVENTS
1974-1989 Increasing awareness of energy and environment issues	1974: 1st seminar on heat pumps for researchers, authorities, builders and real estate owners (BFR, Vattenfall, NUTEK, SP) 1973-1974: International Energy Agency's heat pump group 1975: 1st energy research programme (government support) 1970s: Industry and public funding for demonstration projects (Vattenfall, AGA Thermia, BFR, etc.) 1977-1985: Investment subsidies and loans for households (1977-79; 1979-80; 1980-81; 1981-83; 1983-84; 1984-85) 1979-1985: Energy Prototype and Demonstration Programme: energy guidance training and dissemination of information (municipalities) 1980s: Start of testing activities (SP and industry) 1987: CFC phase out, Montreal Protocol (government commitment)
1990 – 2010 The success story	1990- Continuous research programmes (government support) 1990-1995: Technology procurement programme (NUTEK) including investment subsidies and information campaigns late 1990s: 1st quality label (P-label) for GSHPs (SP) 1998: Introduction of energy advisory offices (municipalities) 1998-99: Subsidies for residential houses to convert from electric heating systems to other energy sources (1998-99; 2001-03; 2006-10) 2006: 1st Swan eco-label for heat pumps (criteria development from 1998 with multiple stakeholder involvement)
BFR: Swedish Building Research (Byggforskningsrådet), after 2001 the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) was formed and included BFR NUTEK: Swedish National Board for Industrial and Technical Development (from 1998, the Swedish Energy Agency) SP: Technical Research Institute of Sweden (Sveriges Tekniska Forskningsinstitut)	

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2.2.3 Renewed support: Switzerland

In Switzerland, a ten year programme called "Energy 2000" was launched in 1990 by the Swiss Federal Office of Energy, followed in 2000 by the "Swiss Energy" programme. These programmes aimed at increasing the use of renewable energy and improving energy efficiency. The use of heat pumps was considered one of the promising pillars to meet quite ambitious goals. In addition to the public financed initiatives of the early 1990s, several measures financed by the private sector were launched. To a large extent, the public and private incentives were coordinated and complemented each other (Rognon, 2008; Rognon, 2006). Policy measures were also adjusted over time to support continuous technical, institutional and economic development. Moreover, several strategic and organisational measures were taken to coordinate the initiatives to support heat pumps. At the Swiss Federal Office of Energy, a position was created to coordinate research, development, technology transfer and market development of heat pumps (Rognon, 2006). In 1993, the Swiss Heat Pump Promotion Group (FWS) was constituted to coordinate market activities. This group involved heat pump producers, distributors, installers, some leading electricity utilities, sector and cantonal authorities and a professional marketing company (Zogg, 2008).

To further support technology development and quality control in the 1990s, a test centre was created in 1993 in Winterthur-Töss. After some scepticism and reluctance, heat pump companies agreed to test their products, which increased confidence in the technology. In 1993-1995 a public subsidy programme was launched for investing in heat pumps in existing buildings. In relative terms, sales increased significantly (by a factor two), but after the subsidy period sales declined again. Although in absolute terms, the subsidy programme did not have a tremendous impact (about 800 units were sold per year), it built up trust in the heat pump technology and was seen as a catalyser for further market development (Rognon, 2006). In 1996, marketing activities were reinforced and the first heat pump exhibition took place. In 1997, subsidy programmes and special electricity tariffs were launched by some utilities, and professional education and training were also improved. In 1998, the Swiss Retrofit Heat Pump Competition Program was launched to develop high efficiency and competitive heat pumps for heating domestic hot water. This programme brought together manufacturers, universities and other actors and was important for creating a common understanding of technology and market development.

In 1997, the canton of Zurich legally restricted the share of non-renewable energies for heating and hot water purposes in new buildings to 80% of the allowed useful energy demand per m^2. Subsequently this requirement was implemented by most of the other Swiss cantons. The requirement could be satisfied either by additional insulation, by using wood or solar energy, or by using heat pumps. As electrically driven heat pumps were a cost-effective option, this legal measure represented a strong policy incentive for the deployment of heat pumps. In 1997, to support energy efficiency and renewable energy in residential buildings, the concept of "Minergie house" was introduced. Minergie is a voluntary standard whose requirements can also be met by using heat pumps. To support product quality, in 1998 the DACH label was introduced for heat pumps. In 2001, the first DACH labels were also given to drilling companies.

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TABLE 2. POLICY INSTRUMENTS AND MAJOR EVENTS RELATED TO HEAT PUMPS IN SWITZERLAND, 1973-2008 (ROGNON, 2008; ROGNON, 2006; ZOGG, 2008)**.** NOTES: SEE TABLE FOOTNOTES FOR ACRONYMS.

PHASE		POLICY INSTRUMENTS AND MAJOR EVENTS
1973 - 1989 Awareness	Increasing awareness of energy and environment issues	1974: 1st guidelines of the Swiss Association for Refrigeration 1980: 1st conference on heat pump technology in Switzerland 1980s: 1st heat pump testing facility (EPFL) 1981/82: Start of heat pump system field testing (NEFF and SFOE) 1983: Meeting on simplification of approval procedure (SFOE and authorities)
1990 - 2010 The success story	1990-1992 First steps	1990: Launch of Energy2000 (SFOE) 1992: Heat pump promotion programme (Energy2000)
	1993-1995 Bundling of activities	1993-1995: Subsidy for heat pumps in existing buildings 1993-1996: Handbooks for better heat pump installations 1995: FAWA - heat pump systems, field testing (SFOE)
	1996-2000 Consolidation	1996: 1st heat pump exhibition (trade fair for the general public) 1997-1998: Subsidies supported by some electricity utilities 1997: Standards including that max. 80% of heat and hot water of new buildings could be covered by non-renewable energies (Canton of Zurich) 1998: Heat pump retrofit programme and competition (R&D and subsidies) 1998: Creation of heat pump quality label DACH (Germany, Austria, Switzerland)
	2001-2005 Industrialisa-tion	2000: Launch of Swiss Energy (follow-up programme of Energy 2000) 2001: DACH label for drilling companies
	2006-2010 Path to independence	2006: Regular 3 day training programme for installers

AWP: Swiss Working Committee of Manufacturers and Distributors (Arbeitsgemeinschaft Wärmepumpen)
EPFL: Swiss Federal Institute of Technology in Lausanne (Ecole Polytechnique Fédéral de Lausanne)
FAWA: field testing of heat pump systems (Feldanalyse Wärmepumpen)
FWS: Swiss Heat Pump Promotion Group (Fördergemeinschaft Wärmepumpen Schweiz)
NEFF: private national energy research fund, sponsored by oil, gas and electricity utilities (Nationaler Energieforschungs Fonds)
SFOE: Swiss Federal Office of Energy
WPZ: Heat Pump Test Centre in Winterthur-Töss

3 EVALUATION OF INNOVATION & DIFFUSION POLICIES

Over time, numerous policy incentives have lined the path of heat pump technology and market development in Sweden and Switzerland. In both countries, the early policy initiatives were poorly coordinated but supported technology development, knowledge development, the involvement of important actors, and market formation. The market collapse in the mid 1980s could have resulted in a total failure – but did not. The research programmes, continuing in the 1980s, and the set of stakeholders and networks formed in the early years, i.e., public and private funded researchers, authorities and institutions, provided an important platform for further development. The influence of informal "advocacy coalitions" (Sabatier and Jenkins-Smith, 1993) supported further development of heat pumps and new policy initiatives (Nilsson et al., 2005).

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In the 1990s and the 2000s both Sweden and Switzerland introduced more strategic, coordinated and flexible policy incentives for the development of heat pumps. The focus was on knowledge development, networking, and market formation, but also on quality control, credibility and legitimacy. R&D, testing & certification was developed in close cooperation with additional strategic market initiatives. Subsidies were introduced as a strategic incentive and catalyst in the 1990s in both Sweden and Switzerland; the role of later subsidies in Sweden is, however, more uncertain. Both countries had a focus on networking, which encouraged important processes of learning. International networking through IEA research may have also played an important role for international learning and spillovers.

3.1 Technology developments

Both in Sweden and Switzerland, continuous government and private R&D support was essential for the development of heat pumps. The R&D programmes supported technical development throughout the boom in heat pump sales in the early 1980s, the market collapse in the mid 1980s and the reinforcement and consolidation of the market in the 1990s and 2000s. Moreover, R&D support extended to the infrastructure in terms of boreholes and drilling processes. In Switzerland, early R&D support in borehole modelling and computer simulation in combination with prior experience in water drilling was essential for heat pump development. In Sweden, less R&D was needed and the development relied on existing experience in water drilling. Both countries developed a leading international position in drilling and boreholes in the early years.

Another key initiative for supporting technology development was the development of test facilities in the 1970s (in Switzerland) and 1980s (in Sweden). In the 1990s the test facilities were considered a vital element for providing reliable and high quality heat pumps. The requirements of testing provided essential quality control and support of the 1990s subsidy programmes. Consequently, the poor reputation of heat pumps from the 1980s could be overcome and credibility re-established. Quality labels were introduced in Switzerland in 1998 and in Sweden in 2005. Quality labels were then also given to drilling companies and drilling installations reflecting the competence of drillers. In Switzerland, the test centre in Winterthur-Töss measured an increase of 20-36% in heat pumps' performance (COP) and energy efficiency between 1992 and 2002 (WPZ, 2001). In Sweden, the Technical Research Institute of Sweden measured 13 - 22% improvement in heat pumps' performance (COP) between 1995 and 2005 (SVEP, 2007).

3.2 Market developments and the involvement of actors

The main driver of the early market development of heat pumps in the 1970s and 1980s was high oil prices. In both countries additional policy instruments accentuated this market demand. In Sweden, the focus was on demonstration programmes and subsidies; the subsidies were, however, fragmented and uncertain. In Switzerland, incentives for market development also addressed networking. In the beginning, market actors involved in both the sale and production of heat pumps were small and working locally. As the market grew in the 1980s the number of actors increased; relevant actors included heat pump manufacturers, retailers, driller and installation suppliers, research organizations, authorities, certifying bodies and test institutes. The collapse of the heat pump market in the mid 1980s, as a result of cheap heating oil (and a subsidy withdrawal in Sweden), reduced the number of heat pump manufacturers and retailers as well as maintenance personnel in both markets. This had severe

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consequences not only on the sales of new heat pumps but also on the maintenance of the installed ones.

In the early 1990s, as a result of increasing concerns about environmental pollution as well as strong lobbying from the advocacy coalition, both Sweden and Switzerland decided to strengthen the heat pump market. In Sweden, a well-coordinated market transformation programme was launched based on a technology procurement programme in combination with test and certification programmes, subsidies and massive information activities. The procurement not only provided high quality technology and substantial market support but also essential interactions among actors. In Switzerland, strategic research activities, subsidies as well as education, training and networking were introduced. As in Sweden, the subsidies were to have a catalytic effect on the market, but were also limited in time. The establishment of organisations for coordination and networking was also important. The programmes in both countries should not be seen in terms of individual policy instruments but rather as strategic and coordinated programmes to re-ignite the market. As a result of these programmes the market for heat pumps took off again. Industrial production ramped up and the number of manufacturers stabilized. In Sweden, “one-stop-shop contractors” were formed – taking responsibility for the entire heat pump system (design, installation and start-up).

In the 2000s, the support of heat pumps continued in both Sweden and Switzerland. In Sweden, market development was, again, supported through subsidies. However, uncertainties regarding the duration and magnitude of these subsidies undermined manufacturers’ long-term investments in technology development. As a result, between 2000 and 2003, 26% of the ground source heat pumps installed in Sweden were reported to have some imperfections (Snaar, 2005). In Switzerland, the market development of heat pumps in the 2000s was driven by law (maximum share of non-renewable energy for heating) and by voluntary standards (“Minergie“ houses). The approaches in Sweden and Switzerland, i.e., subsidies as well as legal requirements and voluntary standards, effectively supported strong market growth in the late 1990s and 2000s. However, the subsidies applied in Sweden over the years have contributed to large government expenditures, in comparison with the use of mandatory and voluntary standards to direct industry expenditure in Switzerland.

3.3 Cost developments

The policy programmes and their effect on increased production and sales of heat pumps have provided opportunities for cost reductions over time. In Switzerland, cost reduction is reflected in the decreasing consumer prices of ground source heat pumps for new single family houses (see Figure 3). During the past three decades, costs have been reduced by more than a factor two. In the early 1980s, the total cost of heat pump systems was almost twice as high as for fossil fuel heating systems; currently heat pumps are cost-competitive. Important drivers of cost reduction have been economies of scale (mass production), not only for heat pumps as such, but also for borehole drilling (for instance, capital costs of drilling systems could be distributed to more clients), and continuous technology improvements. Moreover, parts of the heat pumps are now imported at a lower cost than when produced in Switzerland.

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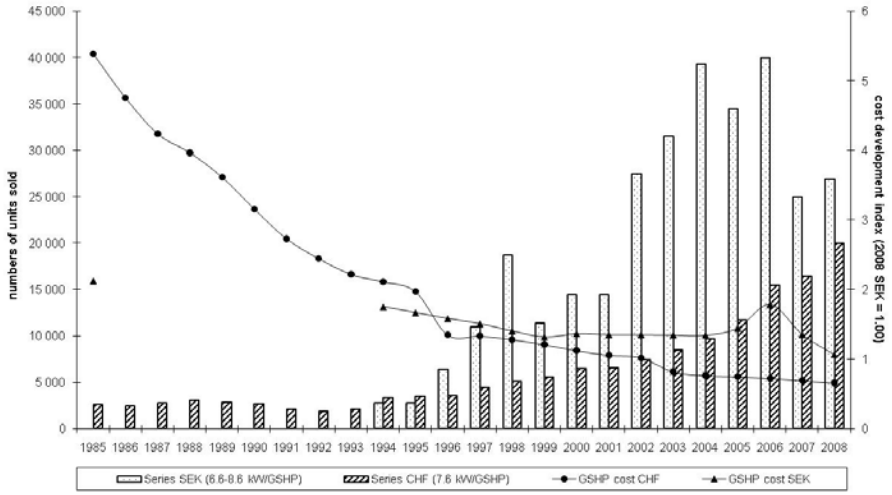

FIGURE 3. NUMBER AND COST OF HEAT PUMPS INSTALLED IN SWEDEN AND SWITZERLAND. NOTES: COSTS INCLUDE THE COST OF HEAT PUMP UNITS AND EXCLUDE COSTS RELATED TO INSTALLATION AND DRILLING. IN SWEDEN, THE SALES FIGURES ARE BASED ON DATA FROM THE SWEDISH HEAT PUMP ASSOCIATION (SVEP, 2007); COST FIGURES IN SWEDISH KRONA (SEK) ARE BASED ON DATA FROM THE SWEDISH ENERGY AGENCY (ENERGIMYNDIGHETEN, 1999; ENERGIMYNDIGHETEN, 2002B; ENERGIMYNDIGHETEN, 2004; ENERGIMYNDIGHETEN, 2006), THE SWEDISH CONSUMER AGENCY (KONSUMENTVERKET, 1986; KONSUMENTVERKET, 2004) AS WELL AS ONLINE TEST MAGAZINES (LAGERGREN, 1995; LAGERGREN, 1999) AND COMPANY PRODUCT SHEETS. IN SWITZERLAND, SALES FIGURES ARE BASED ON DATA FROM BASICS (2002) AND FWS (2009); COST FIGURES IN SWISS FRANCS (CHF) ARE FROM FWS STATISTICS. THE BASE YEAR FOR THE COST INDEX IS 2008, THE BASE CURRENCY IS SEK. PRICES OF SWISS HEAT PUMPS IN CHF ARE CONVERTED INTO SEK USING ANNUAL AVERAGE MARKET EXCHANGE RATES (WWW.OANDA.COM). IN 2008, THE AVERAGE PRICE OF A GROUND SOURCE HEAT PUMP UNIT (6.6 - 8.6 KW) IN SWEDEN AMOUNTED TO AROUND 53,000 SEK (8,140 USD). IN SWITZERLAND, COMPARABLE PRICES FOR HEAT PUMP UNITS OF 7.6 KW WERE AROUND 7,800 CHF (47,000 SEK OR 7,230 USD).

In Sweden, as in Switzerland, consumer prices of ground source heat pumps have reduced over time; however, the trend differs in the two countries. In Sweden, the consumer price merely slightly decreased between 1985 and 1995; despite several drivers of cost reduction (i.e., incremental technology improvements, standardization and industrialization of production) it then remained fairly stable until the mid 2000s. As Figure 3 shows, the cost reduction has been stronger in Switzerland over the years, however, the consumer price level has been lower in Sweden until the beginning of 2000s. The reason for the constant consumer prices in Sweden could include limited competition of contractors and fragmented and uncertain subsidies; however this has not been verified by interviews carried out as part of this study. The price increase in 2006 can clearly be related to the introduction of a subsidy in an already saturated market. Another explanation may be that the components of the Swedish heat pumps are all manufactured in Sweden, whereas manufacturers in Switzerland import most of the components and claim this to be a major source of cost reductions.

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The cost reductions over time observed in Figure 3 are shown in Figure 4 as a learning curve which expresses capital or investment costs as a function of cumulative deployment. The characteristic declining cost profile is clearly seen, as is the contingency of the rate of decline and stabilisation on market conditions (e.g., Swiss and Swedish differences) and technological maturity.

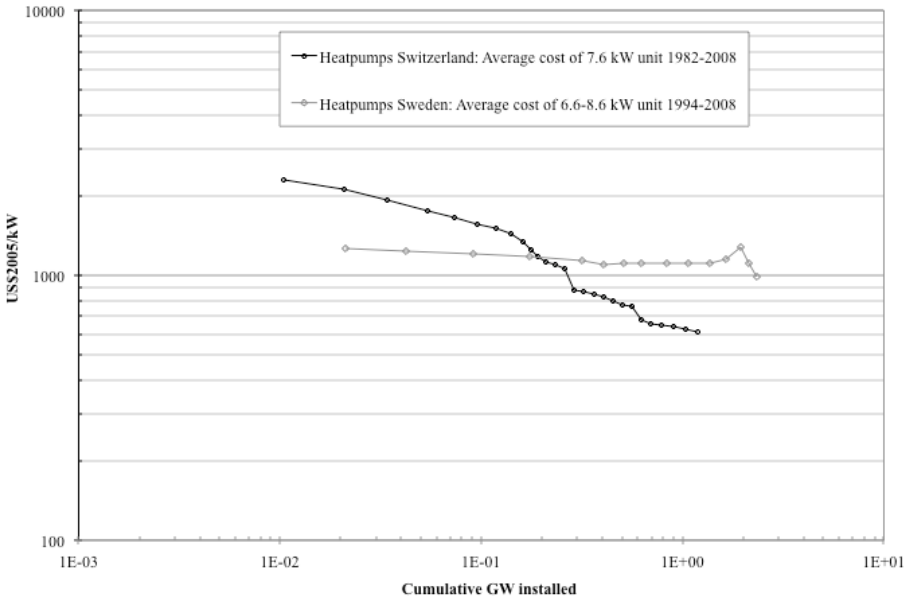

FIGURE 4. COST OF HEAT PUMPS AS A FUNCTION OF CUMULATIVE EXPERIENCE: LEARNING CURVES. NOTE: LOG-SCALE X AND Y AXES.

4 INSIGHTS FOR INNOVATION AND DIFFUSION POLICIES

Assessment of the policy incentives applied in Sweden and Switzerland to support the development of heat pumps and their emerging market can be used to illustrate some important characteristics of policy learning.

First of all, this case study shows the need for long term and continuous support for energy technology innovation. The first attempts to influence the introduction of a new technology may fail, thus continuous support is needed to overcome initial shortcomings. The technology lifecycle, from innovation through to widespread diffusion, takes time. In the case of heat pumps, early government support was introduced in the 1970s but it was not until the 2000s that a major market increase was seen and production was industrialised. Over time, the combination of policy instruments may have to change and the approach used by the government needs to be flexible. Initially, policy may allow and support entrepreneurial testing, but this should be developed into stable strategies over time to allow industry to make long-term investments in standardised products.

Secondly, policy interventions need to consider both the development of the technology and its emerging market and actors. In other words, R&D is necessary but not sufficient. Market formation also

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requires policy incentives that support learning processes related to the use of the products. Moreover, various support for building and strengthening actor-networks is essential for improving strategic integration and learning to ensure feedback and spillover effects.

Thirdly, testing and certification processes are needed not only to support technical quality but also credibility and legitimacy. R&D initiatives as well as subsidies require testing and certification to support a stable market development. Due to an emphasis on quality assurance in the early 1990s, the market of heat pumps started to grow again after having collapsed in the mid 1980s. By establishing a system for quality assurance, both Sweden and Switzerland created reliable products and a high level of public acceptance.

5 FURTHER READING

For an international review of the technical development of heat pumps and the Swiss examples and contribution to this development, see Zogg, 2008. Rognon (2006; 2008) provide a good insight into the role of the state in the promotion of heat pumps on the market. For an overview of the Swedish heat pump market development, see Törnell, 2007.

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