RESPONSIBLE R&D POLICY – A UTILITY OVERVIEW

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Abstract

This paper describes how a power utility, Vattenfall (Swedish part), has acted during a 20 years period with an energy using product of economic signification to the owner and user – the heat pump.

During the monopoly period, up to 1996, this action was based on instructions given Vattenfall from the Government:

- *"..... shall act for an efficient use of electricity within the Country ...".*

In the beginning of the studied period there was also a national political unity of using the Countrys own energy resources as much as possible. That meant that all agreed upon to use the domestic electric energy, hydro and nuclear, even for heating purposes.
Heat pump technology represents one way of using the domestic electric energy for heating purposes.

After the reregulation of the electricity market 1996 Vattenfalls actions on the market is given by its business idea:

- *"Vattenfall´s mission is to enhance its customers´ competitiveness, environment and quality of life through a unique combination of efficient energy solutions and world-class service".*

Heat pump technology represents even now one way of using the electric energy efficiently for heating purposes.

The practical work with heat pump questions has changed over the 20 years for Vattenfall.
During the pioneering period it was much hard ware testing, redesigning and testing again.
When the market had become mature it has been more of working with (expected) win-win concepts together with information, lobbying and promoting of more systems oriented R&D.

Situation in Sweden today related to heat pumps

Today´s energy end use in Sweden

The total annual energy demand of hardly 400 TWh is divided into 155 TWh for the industrial sector, 145 TWh for the building and service sector and the rest for the transport sector.
Of the 155 TWh to industry is 55-57 electricity and of the 145 TWh to building and service sector is around 70 electricity.
The pulp and paper industry uses 40% of the industry´s electricity.
Around 20 TWh of the electricity in the building and service sector is used for heating. One third of all residential single family houses is heated electrically. Of this electricity is approximately 7.5 TWh used for resistent heating.

Climate in Sweden

Sweden is a Northern European country with a population of 9 millions. Because of the Gulf Stream in the Atlantic the climate is relatively moderate but with a large variety between the northern and southern parts. Some basic climate data are given in **Figure 1**.

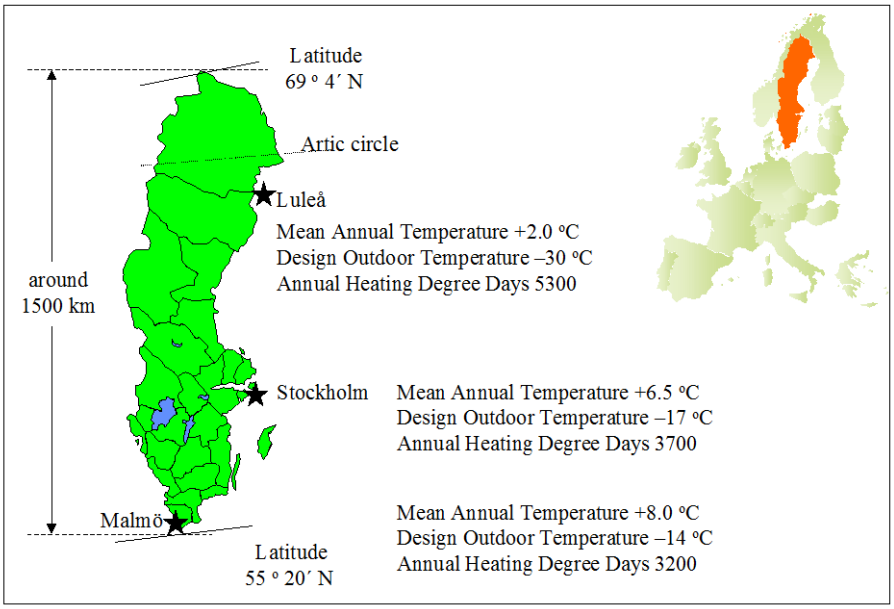

Figure 1 Climatic data in different parts of Sweden

The heat pump situation of today in Sweden

Heat pumps in Sweden today are used mainly in the following sectors:
- industrial sector; mainly mechanical vapor compression for different applications
- district heating sector; generation of heat in the plants
- residential sector; single family house heating and domestic hot water generation

Volumes of heat pumps and heat generated by heat pumps in Sweden today

Industrial sector

The heat generation power of the mechanical vapor compression heat pumps is hardly 160 MW_{th} with an electricity driving power of around 17 MW_e. The equivalent full-capacity operating times vary from subsector to subsector.
The applications are mainly to be found in the dairy, distillery and slaughtery industries and to some part in the pulp and paper industry. The heat generated is used internally in the different plants own processes.

District heating sector

Since Sweden has relatively much district heating even large heat pumps of MW-size are used for heating purposes. A significant part of these heat pumps are absorption heat pumps but the major part is of the mechanical reversed Rankine cycle type.

The heat generated with the reversed Rankine heat pumps is slightly more than 7 TWh_{th} annualy. Assuming 50% of the heat pumps use ground as a heat source with a SPF (Seasonal Performance Factor) of 2.5 the heat extracted – the renewable energy used – is 2.1 TWh_{th}.

Residential sector

The amount of residential heat pumps used in single family houses is around 350 000 of a total number of 1 500 000, vacation houses included.
The heat generated is 6 TWh_{th} annualy using a little more than 2 TWh_e as driving energy. Assuming 75% of the heat pumps use ground as a heat source with a SPF of 2.5 the heat extracted – the renewable energy used – is 2.7 TWh_{th}.

Compared with other European countries Sweden has a leading position and relative its population Sweden is one of the major heat pump nations of the world when it comes to heat pumps for cold climate and heating purpose only; see **Figure 2**. The electricity used has an environmental quality as shown in **Figure 3**.

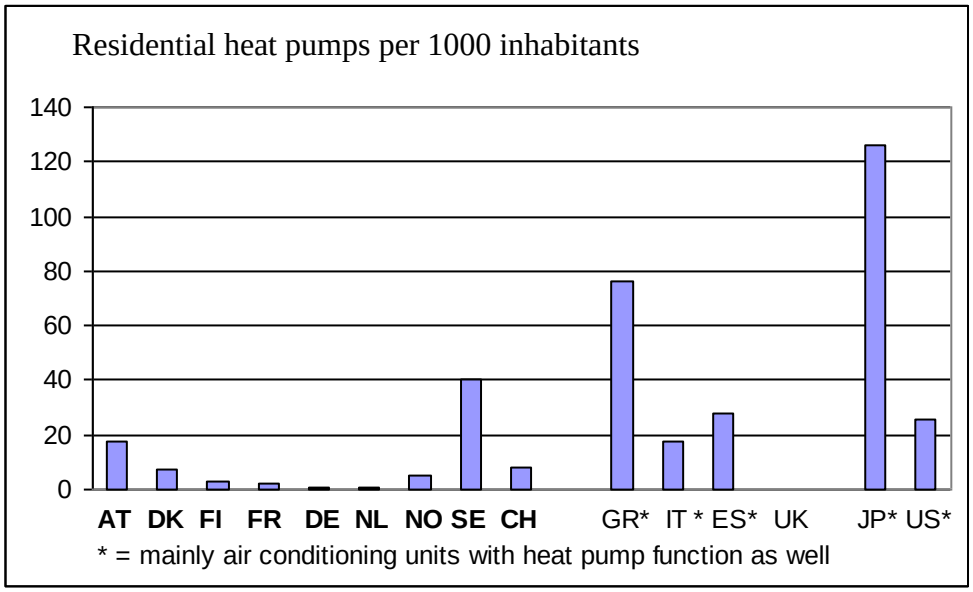

Figure 2 Residential heat pumps per 1000 inhabitants in some countries

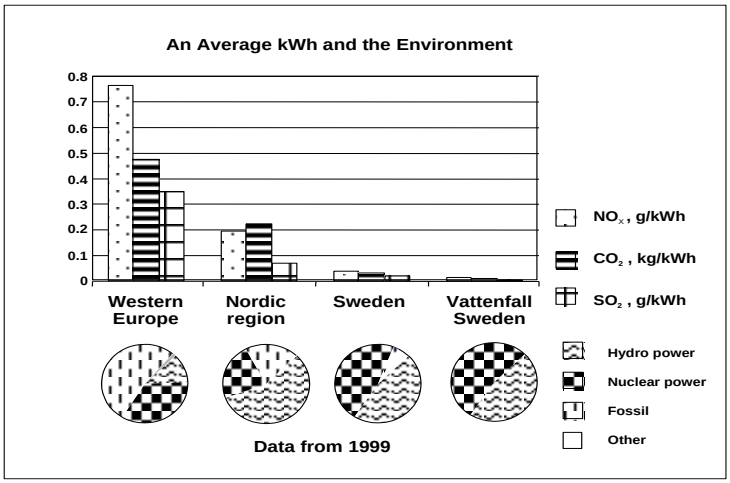

Figure 3 Environmental quality of electricity in Western Europe

Steps towards the Swedish heat pump situation of today

One question after having read the ”Situation in Sweden today related to heat pumps” is:

> How has the Swedish heat pump situation been established?

In the following part of the paper this will be described from a power utilities point of view – from Vattenfall ABs point of view.

Step 1
Before the first oil supply crisis 1973

As in many other European countries the heating demand in different sectores was to a great part satisfied by oil. The relatively new environmental ”green” movement was against the acidification and other disturbances of the nature including among other things the air quality in large cities and municipalities.
As a consequence of this the expansion of district heating accelerated and many cities of Sweden have now their own district heating system installed. These systems serve heating of multifamily houses and commercial buildings like offices, shopping centers etc.
In the same period the competition in the commercial sector led to a growing interest to install air conditioning systems meaning also air cooling in the summer – even in the Nothern European Sweden. This had in some cases the consequence that the owners of the buildings with an air cooling system designed it as a reversible system and used it as a heat pump during the heating season of the year. If they not installed such a reversible system they used the possibility of doing so as a negotiation argument when speaking with the district heating companies on fees and prices of district heating heat.

Many families wanted to live in single family houses; detached houses, semidetached houses, chain houses or terrace houses. This demanded land for buildings, a limited resource in the neighbourhood of the large cities and municipalities where most of the people work. Therefore the building site for each house became very small, 300 – 500 m^2. From environmental reasons these new buildings could not be heated by oil. The smoke from having a separate oil boiler in each house would not be accepted. The houses were instead heated by electricity; with a hydronic system or with a resistent heating system which, both of them, also were cheaper than an oil boiler system. The heating density, $kWh_{th}/(km^2, year)$, is in these areas to low to economically allow district heating systems.

From the middle of the 1960´ies the Swedish power utilities have continued their expansion of electric generation capacity by installing nuclear power.

Step 2
After the first oil supply crisis 1973 up to 1980 with Swedish referendum on nuclear power

As in many other countries with no own oil wells Sweden started 1973-1974 an intensive work of getting more independent of imported oil. At that time there was a national political unity of using the Countrys own energy resources as much as possible. That meant that all agreed upon to use the domestic electric energy; hydro and nuclear, even for heating purposes.

Nuclear fuel was not seen as critical upon as on oil regarding supply security. Large R&D programmes including demonstration projects were established.

When it comes to heating of buildings the main governmental actor was The Swedish Council for Building Research (BFR), replaced 2001 by The Swedish Research Council for Environment, Agricultural and Spatial Planning (Formas). Other governmental actors were at that time The National Swedish Board for Technical Development (STU) mainly responsible for new innovations in different technical sectors. STU was later transformed and renewed in The Swedish National Board for Technical and Industrial Development (NUTEK).

The expanding nuclear power industry during the 1970-ies worried very much the environmental movement - especially the consequencies of a large nuclear power plant accident which could be like the Hiroshima and Nagasaki catastrophes. In Sweden this worry ended up with a referendum in 1980 on the future for nuclear energy. Since there were three alternatives in the referendum the result became no clear, evident ”yes” or ”no” to nuclear energy. Later the Parliament decided to phase out the Swedish nuclear plants, the latest 2010. This fixed year was abolished in 1997. One consequence of this was that it started a still more intensive work on environmentally accepted energy supply and efficient use of energy.

Vattenfall was also engaged in this intensified work, especially with the environmentally accepted supply and the efficient use of electricity. The Swedish electricity market was at that time still a monopoly and Vattenfall was a semi-governmental authority – The Swedish State Power Board - and its instructions among other things was: ”….. shall act for an efficient use of electricity within the Country …”.
One large activity started by Vattenfall at that time was the so called ”Solar Energy Programme”, initiated 1979 and ended 1986.

Step 3
Between 1980 and 1986 – the Heat Pump Establishing Era

Solar Energy Programme of Vattenfall
Since the experiences in Sweden of a large scale use of heat pump systems were very low in the beginning of 1980-ies the main objective for the programme was ”to active work to get solar energy and heat pumps commercially available to a greater extent”. One underlying motive was also of course to get a new electricity market for efficient use of electricity which also should be beneficial for the users. All, even the politicians, still agreed upon to use the domestic electric energy; hydro and nuclear, even for heating purposes.

The Solar Energy Programme can be described as a large trial and error programme maily focusing on heat pumps. The idea was to install many demonstration plants in order to get field experiments and with these experiences make improvements and install newdesigned demonstration heat pump systems. The Solar Energy Programme was not linked to or associated to any manufacturer – it was independent.
The total programme cost was, in todays money, around 70 millions US Dollars.

Vattenfalls own R&D company, Vattenfall Development AB, was engaged in the advanced evaluation of the performance, technical, environmental and economical, of the different demonstration installations as well as in special laboratory tests of separate problems.

Together with the qualified tests and improvements a widespread information of results and experiences was performed as well as education programmes for heat pump contractors together with their trade organisations.

The volume of heat pumps in The Solar Energy Programme is given in the **Figure 4** below.

Heat source	Large sized heat pumps > 1000 kW_{th}	Medium sized heat pumps 25 – 1000 kW_{th}	Small sized heat pumps < 25 kW_{th}
Ground	0	44	33
Rock	0	33	47
Out door air	0	16	134
Lake and Sea	3	24	0
Ground water	0	1	21
Waste air	0	4	56
Exhaust gas	0	0	13
Sewage water	1	1	0
Waste heat	2	0	0
Total number	6	123	304
Total thermal power, MW_{th}	31	12	2
Annual thermal energy, GWh_{th}	160	31	4

Figure 4 Number of heat pumps studied in the Vattenfall Solar Energy Programme 1979 - 1986

Around 25 different manufacturers were represented from which Vattenfall, as a competent purchaser, bought all the 433 heat pumps.

Regarding large sized heat pumps (heat pumps for the district heating sector),Vattenfalls pioneering work during this period led to a very rapid expansion of district heating heat pumps and the potential market was reached within around 5 to 10 years. Today many of these heat pump installations are also used for district cooling – meaning a twofold benefit from the machinery.

The market for the medium sized heat pumps has not been so sucessful as that for the large sized heat pumps and that for the small sized heat pumps (residential sector).

The three most important experiences were:
1. A heat pump is not the same as a reversed cooling unit. A heat pump has to compete with other heating devices and must be designed to win that competition.
2. A heat pump installed in a heating system do not behave as the ”common” heating devices like boilers and furnaces. A heat pump system must therefore be controlled in another way than heating systems with common heating devices.
3. Do not complicate the design – you may have enough problems with the simple systems.

Together with the technical work Vattenfall also argued for heat pump friendly legislation, building and environmental codes, customer friendly subsidies, guarantees etc.

Vattenfall also worked internationally with other utilities on heat pump systems and heat pump experiencies. The executive manager of The Solar Energy Programme, Bengt Nordström, initiated a utility network on heat pumps; IPUHPC (International Power Utilities Heat Pump Committee). This committee had and still have to some extent cooperation with IEAHPC (International Energy Agency Heat Pump Center).

Other heat pump actors

The growing interest of heat pumps, from especially the residential sector, made it very important to have consistent and well known definitions of what a heat pump is, what a COP (Coefficient Of Performance) is, what a SPF (Seasonal Performance Factor) is etc etc.
The needs for objective and reliable information increased and some official authorities put themselves on the heat pump arena to prevent the not serious heat pump actors to enter the market. Some of these official authorities were and still are:

- The National Swedish Board for Consumers Policies (KOV),
  an authority which gradually enlarged its information – prestanda and costs on a comparable manner - on heating devices för single family houses including heat pumps
- The Swedish National Testing and Research Institute (SP),
  an independent testing institute which worked on behalf of, among others, KOV generating the data on which KOV based its information.
  SP also worked with standardisation regarding heat pumps. This work included all kinds and sizes and types of heat pumps, definitions as well as measurement standards. SP and Vattenfall, especially Vattenfall Development AB, cooperated on many of these issues during this period.
- BFR intensified their studies on heat pumps including different heat sources, systems applications and integration of heat pumps in buildings. BFR´s work also influenced the building codes so that low temperature hydronic heat distribution systems now can be installed – a boundary condition that makes it possible to lower the condensation temperature thus increasing the effiency of the heat pump systems.

Involved in many activities were and still are the technical universities, mainly The Royal Institute of Technology (KTH) in Stockholm, The Chalmers University of Technology (CTH) in Gothenburg and The Lund University (LTH) in Lund.

To stimulate installations of building heating systems using other energy than oil, the Swedish Government during some periods subsidised such installations – even heat pumps.

Step 4
From 1987 to January 1st 1996 the reregulation year of the electricity market

When the Vattenfall Solar Energy Programme finished in 1986 the heat pump was a concept that many single family house owners were familiar with, even if they not understand how in detail a heat pump works. The potential market now knows what the product is. If this potential market will accept and buy the product now became a challenge for the heat pump manufacturers and sellers.

Some of the Swedish heat pump manufacturers have learnt a lot during the first years of the 1980-ies to, I will say, a great extent because of Vattenfalls Solar Energy Programme. These manufacturers were now gradually starting harvesting from their own efforts and investments in heat pumps.
Other actors on the heat pump market – the not so serious companies – slowly disappeared from the market. This process was supported by the new heat pump trade organisation(s) that

the more serious manufacturers have created. One of these organisations is specially devoted to heat pumps: The Swedish Heat Pump Association (SVEP). SVEP, among other things, offers customers to their members a special 5-year guarantee thus indicating a serious approach to their products. For cases of special conflicts a so-called Heat Pump Jury has also been established headed of a professional judge with representatives of the manufacturers and consumer organisations.

To encourage the energy product manufacturers to design and produce more energy efficient products the governmental authorities, first NUTEK then the The Swedish Energy Agency (STEM), introduced the so called Technical Procurement. This is a product development process in the form of a competition where the winner is guaranteed a limited market for its product. The product shall meet a certain number of minimum performance objectives and the manufacturer which has the best solution is declared as the ”winner” of the Technical Procurement competition. Such a Technical Procurement competition has also been arranged for heat pumps. It is considered as a good example of the Technical Procurement concept.

Vattenfall made an attempt to act as a Heat Pump Energy Service Company (HP-ESCO) some years after the Solar Energy Programme was finished. The experiences were not encouraging so this HP-ESCO was winded up. The main reason, as I see it, was that Vattenfall was not equipped to act as an installation contractor of this kind of small systems (compared with ordinary power utility businesses). Another reason was the fact that some, in the business engaged managers, did not realise that you are selling a heating system and not only a product/component using electricity. To this could also be added the awakening interest and focus on the reregulation of the electricity market.

Parallell to this heat pump expansion in Sweden the ozone depletion problem caused by the refrigerants CFC and HCFC and the green house effect of these and many other gases and refrigerants have given new problems for the heat pump (and refrigeration) industry to solve. Even here the leading Swedish heat pump manufacturers have so far solved the problems acceptably.

Step 5
After January 1st 1996, the beginning of the reregulated electricity market, up till today

The reregulation of the electricity market established a competition regarding electricity sales and electricity generation. The transmission and distribution are still monopolies.

This competition created a hard press on the electricity prices and they have dropped very much since 1997. The first year 1996 was in Scandinavia a so called ”dry year” combined with not so mild winter that the prices did not drop that much this year. 50 – 60% of the electricity generation in Scandinavia is hydro power.

The electric energy prices on the common market place in Scandinavia, Nord-Pool, are given in the **Figure 5** below. It shall be notified that the prices are only energy prices excluding transmission and distribution prices and all kind of taxes.

The decreasing electricity prices led to decreased profits for the utilities and as a consequence to a much harder selection of the product portofolio.

Focusing on core business and choosing the new product areas very careful became the strategy - still in operation. The support to the now mature heat pump market is not needed in the scale that existed earlier during the pioneering period.

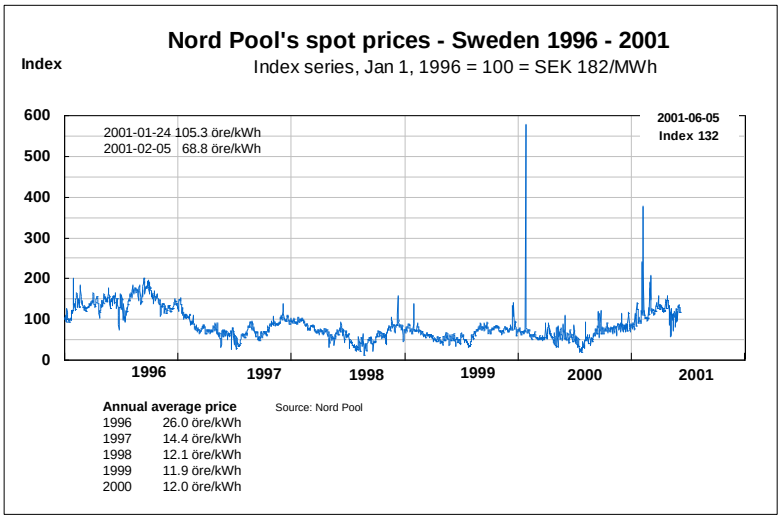

Figure 5 Electric energy spot prices on the Nord Pool – Sweden from 1996
182 SEK = 18 US Dollars

Conclusions

During a period of 20 years heat pumps have become one sector of the mature market of equipment for heating of buildings and generation of domestic hot water in Sweden. This has been a joint work of many actors, from the Government through different R&D and product development organisations and individual heat pump manufacturers to the individual heat pump owner and user.

Vattenfall has been one of the important actors, especially through its Solar Energy Programme with its entrepreneural executive manager. One reason for this programme being so sucessful was also the lucky excellent timing. When this programme started:

- The realistic alternative to the, by price chocks, expensive oil was electricity
- The during the 1960-ies planned electricity generation expansion was almost completed
- The district heating system operators were looking for cheaper fuels
- The families had started a single family house building boom in the late 1960-ies and in the 1970-ies. The houses were mostly equipped with electric heating.

All these factors were in favour for heat pumps.

As a good summary of what is needed for a sucessful work with for example heat pumps is given in **Figure 6**.

From the figure it can be seen that to have a *Technical-economical potential* for a concept is not enough.
You also need so called Acceptance and Penetration power.

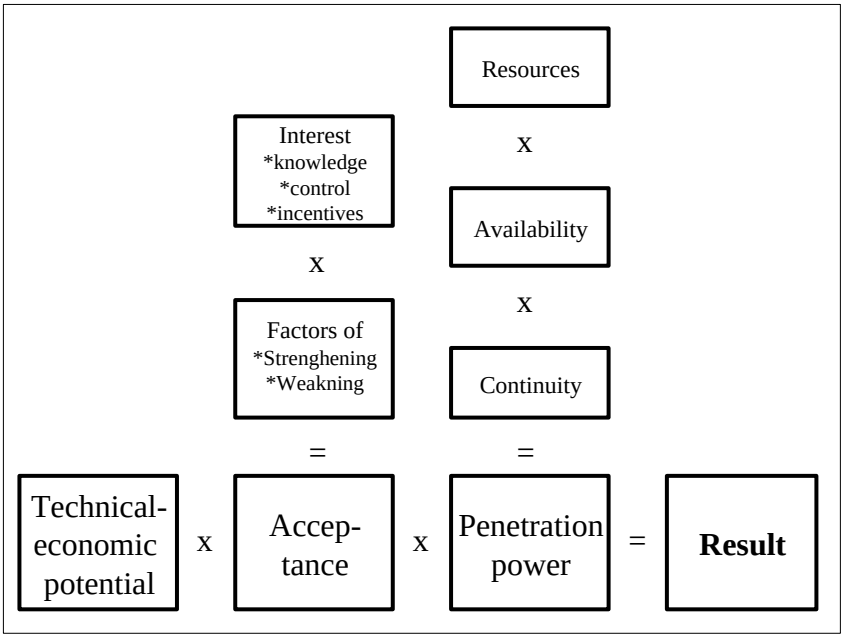

Figure 6 Cooperating factors to reach the market

Acceptance
The process of making a potential customer aware of the existing possibilities for a change of something is an important step in introducing new products, among other things heat pumps. Important for a potential customer is to have an Interest in the product in question. This interest depends on her/his knowledge of the product, on her/his possibilities of control of the situation established by the product and on other incentives, except the economy, she/he has. This process can be called the Acceptance process and can be accelerated by eliminating the Weakning factors and stimulate the Strenghening factors regarding knowledge, control and incentives.

Penetration power
A mental acceptance is however not enough to have things happen. There must also exist a Penetration power making the mental acceptance transformed into genuine action. This needs Resources, money and people, Availability, the money and the people at the right time, and Continuity, the money and the people enough long time to finish the concept in question.

The Future

Vattenfalls strategy in Sweden today when it comes to the mature heat pump market can be summarized under the following three main points:

- Efficiency
  - Promote systems with good SPF in the right systems
  - Support R&D for heat pump applications in the right systems
  - Do not support hard ware manufacturing

- Ecology
  - Compare the environmental impact of heat pump systems with other heating systems
  - Support with TEWI (Total Equivalent Warming Impact) data
  - Follow the refrigerant question
- Economy
  - Compare the economy of heat pumps with other heating systems
  - Join only (expected) win-win cases
  - Use heat pumps as one way of defending the electricity market

This strategy indicates a direction towards more of information and lobbying instead of subsidising on a now mature market. The strategy also includes promoting systems oriented R&D instead of components oriented R&D.
One important question that still is waiting for a good solution is how to energize the peak power and peak energy. To do it with electricity is not very clever in areas where the electric energy peak power and peak energy appear at the same time as the heat peak power and peak energy.

Vattenfall has and is in the latest years, through ELFORSK The Swedish Electrical Utilities´ R&D Company, one participator in STEM´s industry-university R&D programmes Climate 21 ”More Efficient Refrigeration Machines and Heat Pumps” and eff-Sys ”More Efficient Refrigeration and Heat Pump Systems”.
The author has been and is a member of the Steering Groups of these two STEM programmes. He is also chairman of the separate ELFORSK group established to coordinate the power utilities ideas on the programmes.

How Vattenfall will act on other markets than the Swedish regarding heat pumps is not yet decided. Vattenfall operates today in Nothern Europe mainly in Finland and parts of Germany and Poland.

Vattenfall is also worldwide, through its consulting daughter company SwedPower International AB, offering others help with different energy problems, among other things heat pumps.

Acknowledgments

I will thank all my collegues in the heat pump sector as well as in the power utility sector for all information and knowledge given to me during all the years I have worked with the sectors.

Many thanks also to Mr Jos Bouma of IEAHPC and Dr Peter Rohlin of STEM. They both inspired me to this attempt to condense my 20 years of experiences from my work with heat pump systems and power utilities.

Nomenclature

Abbreviation	Full form	Comments
AHDD	Annual Heating Degree Days	room temperature + 17°C, heating stops at an outdoor temperature of +11°C
COP	Coefficient Of Performance	a power factor
HP-ESCO	Heat Pump Energy Service Company	
SPF	Seasonal Performance Factor	an annual energy factor
TEWI	Total Equivalent Warming Impact	a CO_2-equivalent factor including other green house gases than CO_2

Abbreviation	Full name of the organisation
BFR	The Swedish Council for Building Research
CTH	The Chalmers University of Technology in Gothenburg
EHPA	The European Heat Pump Association
Formas	The Swedish Research Council for Environment, Agricultural and Spatial Planning
IEAHPC	The International Energy Agency Heat Pump Center
IPUHPC	The International Power Utilities Heat Pump Committee
KOV	The National Swedish Board for Comsumers Policies
KTH	The Royal Institute of Technology in Stockholm
LTH	The Lund University in Lund
SP	The Swedish National Testing and Research Institute
SVEP	The Swedish Heat Pump Association
STEM	The Swedish Energy Agency

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