Long Term Market Transformation from a Short Term Subsidy: Energy Savings from Residential Air-to-Air Heat Pumps in Norway

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Abstract

In the winter of 2003, a once-off subsidy program was launched in Norway to stimulate the diffusion of efficient and electricity-saving heating technologies in the household sector. Air-to-air heat pumps was one of the technologies that were subsidized. During the 1990s, the national market for air-to-air heat pumps was approximately one thousand units per year. The sales trend shows a distinct break in the 2002-03 heating season, and after a period with rapid growth sales have grown to around eighty thousand units annually. In this paper we estimate energy savings from the 2003 Household Subsidy Program (HSP) and a subsequent revised version of the program. First, an analysis is performed to identify the most likely autonomous market development. Three different approaches are used to establish this contrafactual baseline: (i) expert assessment, (ii) between countries comparison of heat pump market trends, and (iii) econometric market analyses. The difference between the observed sales and the baseline represents the estimated market effect of the HSP. Second, micro-level analysis of metered electricity consumption in the households participating in the HSP gives the per unit net energy savings needed to calculate the energy savings resulting from the Norwegian HSP. The 2010 accumulated added annual electricity savings resulting from the HSP are about 1.1 TWh or 3 % of total annual electricity consumption in the Norwegian household sector.

Background – the Norwegian household sector

What characterizes household energy use in Norway? Due to historical reasons, we now have a situation where close to 80 % of the energy supply for stationary energy use in the household sector comes from electricity, and more than 60 % of the electricity used in the domestic sector is for space heating (Grinden and Feilberg, 2009). Almost all domestic electricity production is from hydropower. This dependence on electricity is challenging for the electricity system for reasons of both power and energy capacities, particularly in the dry and/or cold years. Reducing this dependence on electricity, through energy efficiency and alternative heating technologies, therefore is a major goal of Norwegian energy policies. The second argument for saving electric energy is climate. Hydropower is “clean” energy, and exports of surpluses in the domestic market can replace CO_2-emitting electricity production in the European market. Saving kilowatt-hours of electricity in Norway thus may reduce European carbon emissions. (OED, 2008).

In 2001 the national energy agency Enova SF was established. Enova’s mission is stated as that of achieving an efficient stationary end use of energy with a secure and sustainable supply. Market transformation processes are central in these strategies. In 2003 Enova launched a program to introduce new electricity saving heating technologies (heat pumps, pellet stoves, and heat control systems). The purpose of this article is to analyze the market transformation effects of this program on one of the technologies, namely air-to-air heat pumps. More specifically, we wish to evaluate the market effects of the program in terms of sales of heat pumps and the electricity savings due to these effects.

The text is organized the following way: In the next section the theoretical underpinning of the Enova programs is presented, followed by a discussion of the different effects that can be expected from these programs. The last sections present the empirical analyses and discuss the findings and their implications.

Theoretical basis and principles

A fundamental idea of the Enova approach is to achieve long term changes (transformation) of the markets that are relevant for Enova's mission. This approach recognizes that there are deviations between current energy behaviors of the actors in the target groups, and the socially desired energy behaviors. By *energy behavior* we mean any decision by a relevant decision maker (building owner or renter) that affects the stationary energy use of the decision unit. Energy behavior thus ranges from the daily habitual behaviors to larger building and technology investments. The long term market transformation that Enova aims for, implies that the choices characterizing socially desired energy behaviors become the natural choices of decision makers in the relevant decision process. Government interventions of different kinds and strengths are needed to initiate this market transformation, but in the long run markets need to incorporate sustainable and ongoing end use efficiency without government interventions.

Enova's program design builds on two theoretical platforms. The first is a robust understanding of decision making in the target groups, for which theories on micro level energy behavior decisions are central. Second, theories at a more aggregate level for understanding how innovative behaviors spread in a market are also important, together with the link between these market diffusion theories and the micro level theory. Insights from these theoretical platforms give direction for the design of the most efficient policy instruments. These concepts are briefly discussed below.

Micro level energy behavior

Traditionally, energy behaviors, in particular those behaviors that involve an investment decision, have been studied within the realms of the neoclassical rational actor model. The discussion of the "energy paradox" may be viewed as a response to and attempts to explain why so many energy related decisions seem to be out of line with the neoclassical model, particularly why many seemingly profitable investments are not undertaken. The energy paradox is discussed, among others, by Jaffe and Stavins (1994) and Golove and Eto (1996).

Over time the theoretical base for energy behavior has broadened. We find it useful to expand the neoclassical model with elements from social psychological behavior models, such as the Theory of Reasoned Action (Fishbein and Ajzen, 2010), formerly known also as the Theory of Planned Behavior (Ajzen, 1991). This fundamentally micro level model can be further expanded by adding explanatory variables relating to the societal level (Egmond and Bruel, 2007) in order to explain individual energy behavior.

Market transformation

Individual decisions make up the market development process. There is a relationship between decisions at the individual level and the diffusion of a certain behavior in a target group. Understanding this relationship and the diffusion process, is aided by theories of the diffusion of innovations.

Empirical evidence suggests that adoption in a target group of a certain technology or specific behavior follows a recognizable pattern. This idea has been formalized by Rogers (2003). There are three main points to be made regarding this diffusion theory. First, the diffusion over time of the technology or behavior in question typically follows an S-shaped curve. This means that diffusion is slow and limited in the initial phases, then speeds up before it slows again, reaching a saturation level. Second, this pattern is often explained by psychological differences among adopters. Innovators and early adopters are the segments adopting first, followed by mainstream segments and finally the “laggards”. These segments can be characterized by different scores on key explanatory variables of the energy behavior model, such as risk aversion, attitudes toward new technology or behaviors, etc. The third point is that diffusion does not necessarily proceed in a continuous fashion once it has commenced. Often one finds barriers between the segments that may slow or even stop the diffusion between two segments. Of particular interest is the transition between early adopters and the early mainstream market. The diffusion of many innovations stops here, and Moore (2002) introduced the concept of the “chasm” to characterize this critical phase.

Enova is motivated by these theoretical building blocks in the design of its market transformation processes. The design of the instrument portfolio reflects the key concepts of the decision model and the diffusion theory and addresses the barriers that are perceived to hinder diffusion at different stages of the diffusion (or market transformation) process. This is summarized in Figure 1.

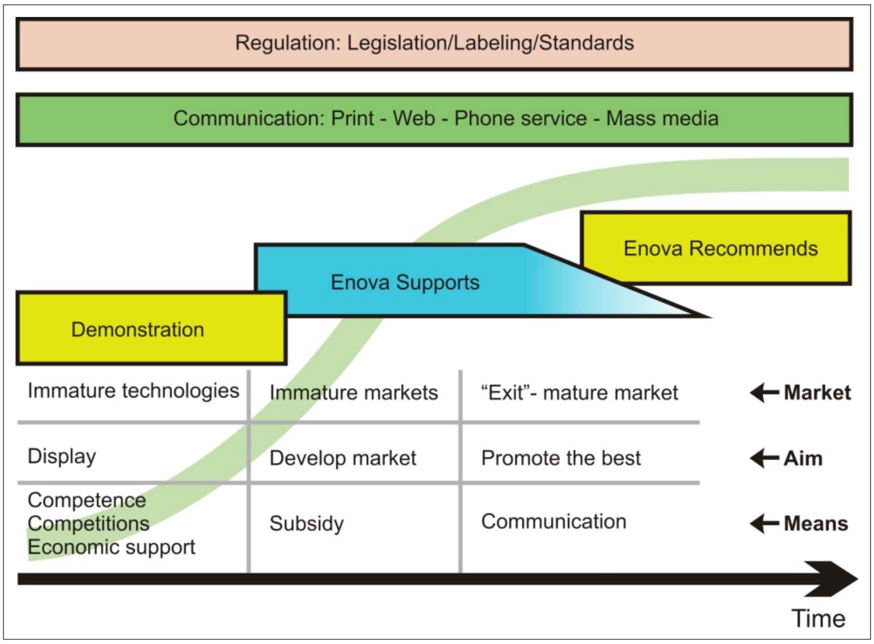

Figure 1. The Enova model: different policy instruments applied at different stages of the market diffusion process.

Program effects

Enova’s mission is to initiate market processes to achieve a higher degree of efficiency in energy use and to ensure a secure and sustainable supply of energy. The current energy system is characterized by large known potentials for energy efficiency and a vulnerable and capacity limited power grid. The relatively high dependence on electric energy for heating in Norway is central to these challenges. We may describe a future state where Enova has accomplished its mission the following way: First, energy efficiency potentials are exhausted in the sense that energy efficiency technologies (behaviors) in the different sectors are used up to the point where their marginal social costs equal the marginal social cost of new energy production. Second, this socially optimal state is achieved through an individually optimized marked behavior by the different market actors. Thus, in the long run, markets should work in this respect without the presence of government interventions.

The model in Figure 1 gives principles for intervention mechanisms to achieve this market transformation. As for any large scale policy of social change, the desired outcome is not guaranteed. Periodical evaluations are necessary in order to improve the programs and ensure that they are working properly. Enova operates with different program effects as indicators that the market transformation is working. The four categories of program effects are the following:

1) Direct results

The direct results are changes in energy behavior that are achieved as a result of contractual participation in one of Enova's programs. It is assumed that the project measures would not have been carried out without the support from Enova. Examples of programs that give or have given direct results are subsidy programs for energy retrofitting of existing buildings, bioenergy heat production and district heating programs, the household subsidy program, etc.

2) Direct effects

These effects are (changes in) energy behaviors that are triggered by programs offered by Enova, but without the contractual relationship assumed for the direct result. Programs that give rise to these kinds of effects will typically be communications activities. Like for direct result effects, we also assume that the behaviors would not have happened without the influence of Enova. The principle of Enova triggering the actual behavior is fundamental in the two first categories of effects.

3) Changes in behavioral intentions

The theoretical models for energy behavior briefly discussed above, imply hypotheses that there may exist, for some behaviors, a time-lag between the relevant changes in influential determinants (explanatory variables) and actual behavior. This means that an energy program may influence the behavioral determinants of the decision maker and move him or her to a mode of greater behavioral preparedness, typically relevant for investment behaviors. As opposed to effects 1 and 2 above, the actual observable behavior will take place later in time, although the effect of the program has been significant in aiding the decision maker to form a behavioral intention. The development over time of important determinants of energy behavior is therefore also a relevant effect of Enova's programs.

4) Market transformation

The ultimate desired effect of Enova's efforts is that of market transformation. This effect is the diffusion of socially desired energy behaviors that may be caused by permanent structural changes in the supply and/or demand functions that cannot be classified as direct result or direct effects (1 and 2 above), but that also would not have taken place in the absence of Enova's behavior change program(s). This type of effects represents the long term goal of Enova's work.

These four program effects will always have to be related to a "neutral" *baseline* situation where no public intervention is present. The baseline in this case is the market development we (most likely) would have observed, had there been no public programs to induce a market transformation. These effects and the baseline are illustrated in Figure 2.

The ”Enova-effect" measured as the difference between the observed and baseline market development, is the sum of the four effects. It may be difficult to exactly delineate the individual effects, however there are assumed dynamics in this development. The direct result is the easiest to identify, although not trivial (e.g. the free rider problem). The direct effect is harder to measure, but conceptually well understood. The changes in behavioral intentions cannot be measured in terms of number of sales, but will be manifested in subsequent direct effects or market transformation effect.

There is a dynamic relation between these effects, effects 1 and 2 being the concrete immediate effects of the programs, while 3 and 4 are the more persistent long term effects remaining and driving the market after termination or down-scaling of the public programs.

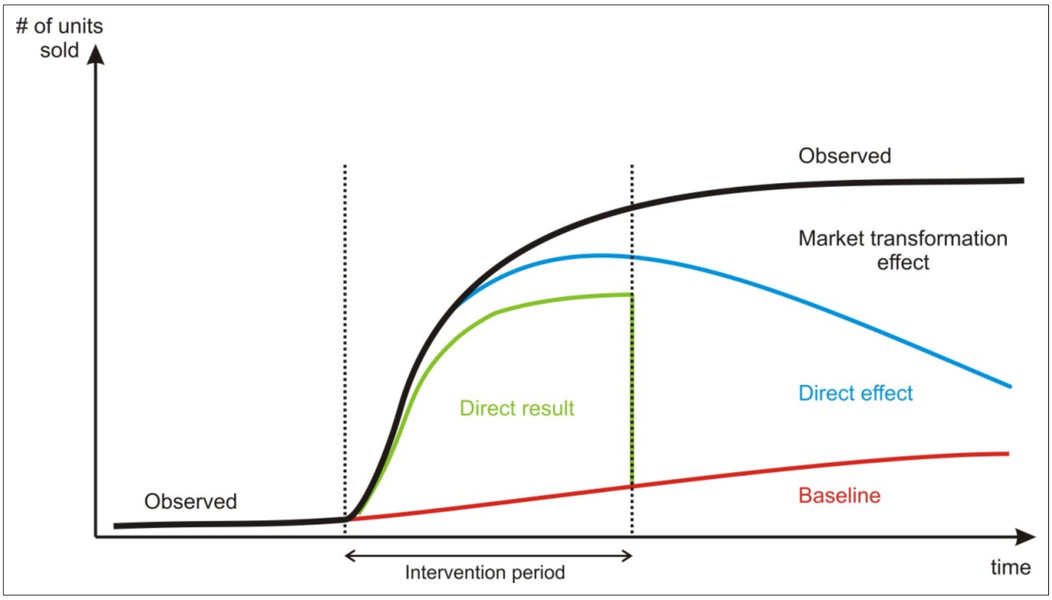

Figure 2. Components of the market transformation process

How do we distinguish between, and measure, the different effects of energy behavior change programs? In this analysis we do not attempt to separate these four effects. Instead we view the aggregated effect of a program (or program portfolio) as the observed market development (e.g. annual sales volume of an energy technology) less the non-observed but estimated baseline sales development.

Estimating market transformation effects

We now turn from theory and principles to empirical estimation. The annual sales of air-to-air heat pumps are readily available in the form of a time series from 1992. The counterfactual estimation of the baseline is the main challenge in this analysis. The approach is discussed below. An important input to the baseline estimation is the design of the Enova programs of relevance for the market development of air-to-air heat pumps. Therefore we start by discussing these programs.

Enova's 2003 Household Subsidy Program (HSP)

As a response to the sharply rising electricity prices and the heated public debate in the winter of 2002-03, the Norwegian government decided to initiate a subsidy program with a goal to stimulate investments in alternative heating technologies in the household sector, to be administered by Enova. A main goal with the program was to contribute to a reduced dependence among households on electric heating, either by more efficient use of electricity or by introducing alternative heating sources. The resulting program supported three household heating technologies; (i) heat pumps, mainly air-to-air, (ii) control systems for electric heaters, and (iii) wood pellet stoves. Satisfying the program criteria, the households would receive a subsidy of up to 20 % of the investment cost (limited to NOK 5 000/€ 610 for heat pumps and pellet stoves and NOK 2 000/€ 245 for control systems). The program opened for applications on February 1, 2003 and closed on March 15 (Bjørnstad et al., 2005).

Although more than 47 000 households applied, only around 19 700 presented the required documentation of purchase and installation, thus actually receiving the subsidy payment. A total amount of NOK 83 million (approx. € 10 million) was given as subsidies to households under the HSP. Heat pumps were by far the most popular of these heating technologies, as more than 92 % of the households which received subsidies invested in an air-to-air heat pump. A general conclusion from the evaluation of the program is that the air-to-air heat pumps appear to be an attractive investment due to heating comfort, ease of use, and energy economics.

Enova's 2006 HSP

The Household Subsidy Program was continued in 2006 in a similar design as the 2003 program. A major difference was that air-to-air heat pumps had been removed from the portfolio of supported technologies. The main reason for this is that this technology had shown such a positive market development after the 2003 program, in addition to being a very profitable technology, thus a continued subsidy was not warranted. Other heat pump designs, including hydronic systems, such as air-liquid and liquid-liquid were subsidized also under the 2006 HSP. The program is still running as we enter 2012, but with some minor changes along the way.

In addition to the HSP, Enova offers web resources, information and purchase advice, a free online and phone energy advice service and advertisement campaigns that complement and amplify the HSP.

Estimating the baseline

It is inherently difficult to estimate a market development that cannot be observed. We chose to use three different approaches to quantify the counterfactual baseline for the air-to-air heat pump market. These are: (i) expert assessment, (ii) comparison of market development between countries, and (iii) econometric market analyses. We discuss these approaches in turn.

Expert assessment

Market actors who have been working in the heat pump market over time develop a sense of understanding of the mechanisms governing the market. One such actor is the Norwegian Heat Pump Association (NOVAP). We presented to the most prominent expert in the association the following question: *Recall the market development for air-to-air heat pumps in Norway during the 1990s and up to 2002, before the launch of the 2003 Household Subsidy Program. Given the historical heat pump sales and the market situation in 2002, what would have been your best estimate for the development of the domestic air-to-air heat pump market for the coming decade?* In this interview situation the expert considered several factors, such as the improved technical state of the technology, the international development regarding this heating technology, the development and latest changes in the domestic electricity market, and so on, before arriving at a baseline estimate for the market. The market estimate was presented as number of units sold per year in the period after 2002. The expert naturally did this as an ex-post exercise with full knowledge about the factual development of the heat pump market. This baseline estimate was also challenged and adjusted in discussions with experts in other relevant Norwegian organizations. The estimated expert baseline is drawn in Figure 3.

Comparison between different countries

A second reference suitable for estimating the Norwegian baseline is the Swedish market for the same technology. Many of the characteristics making Norway suitable for a rapid diffusion of heat pumps, are similar. Sweden has many single houses with direct electrical heating, similar climate, similar heating culture, and similar political and economic framework conditions. The

Swedish household electricity price, however, was (and is) generally somewhat higher than in Norway. The most notable difference between Sweden and Norway is that the market for domestic-size air-to-air heat pumps was not subject to any Swedish government interventions. The unsubsidized Swedish market for air-to-air heat pumps thus may serve as an indicator for the non-observed development of the Norwegian market. We have scaled the development in Sweden according to the differences in housing stock to arrive at a baseline estimate for the Norwegian market in absence of a subsidy scheme. This estimate is labeled as "country comparison" in Figure 3.

Econometric methods

The third main approach was to apply econometric techniques to model the market development. While the two approaches described above attempt to explicitly estimate the baseline, the econometric methods have a different logic. These methods model the full set of explanatory variables for the observed market development. As a subset of these variables, the Enova-related variables (described below) explain the total "Enova-effect". This effect includes the direct result and the direct effect (ref. Figure 2). Remaining variation in the heat pump sales development, either due to other than the Enova-related variables, or unexplained residual, is defined as the baseline. Since it is difficult to delineate market transformation effects in these models, it is likely that these remaining effects represent a mix of the "true" baseline and market transformation effects. The baselines estimated from the econometric methods in Figure 3 thus overstate the value of the baseline, and can be viewed as a conservative estimate in terms of not overestimating the effect of the Enova programs.

We have formulated several models in order to explain the air-to-air heat pump sales by our explanatory variables. The choice of models is based on a trade-off between several competing goals: We aim for models that are parsimonious, robust and with a high explanatory power, while at the same time in compliance with assumptions for OLS and econometric time series modeling.

In this paper we estimate one optimistic and one conservative version of ordinary time series regression models with dynamic elements. In addition to the usual pitfalls of OLS estimation techniques, the dynamic elements add estimation challenges in that there might be autoregressive components of the variables that should be accounted for in the model. A well specified model is capable of handling these issues.

We also estimate an error correction model (ECM). This model has a different structure and is less straightforward in interpretation, but it can often be more robust against the potential statistical challenges of dynamic modeling.

Our empirical estimation is based on the time series of annual total sales of air-to-air heat pumps in Norway over a period stretching from 1992 to 2010. Statistics are obtained from the sales data collected and kindly made available to the authors by the Norwegian Heat Pump Association (NOVAP, 2011). This is the dependent (left hand side) variable in the ordinary time series regression models. The error correction model explains the annual difference in sales instead of the actual sales level.

Explanatory variables

We use the following explanatory variables to explain sales in the econometric models:

i) Heating need

Heating need in the homes is a function of the outdoor temperature, and is measured by the *degree days* over the calendar year with 17 °C as the threshold temperature. The population-weighted average regional annual heating degree days are used to indicate the annual heating need during the study period.

We hypothesize that the variations in heating need explain part of the variation in the demand for air-to-air heat pumps. High heating need in a given year induces a purchase of a heat pump in the same year or in the following year. The latter is accounted for in the model by including a one period lag of the degree days variable. Data for this variable is obtained from the Norwegian Meteorological Institute (2011) combined with population statistics from Statistics Norway (2011a).

ii) Household consumption

The sales of heat pumps could be explained by the level of disposable income in the households: The more income disposable for consumption, the higher the demand for heat pumps. We use the household consumption statistics from the national accounts from Statistics Norway (Statistics Norway 2011b) to represent this variable. The variable gives the average values per household in NOK 1000. Values are adjusted for the changes in the consumer price index (CPI) with 1998 as the reference year. In addition to the level of consumption, a variable to represent the change (difference) from one year to the next is also included.

iii) Price of electric energy

As many Norwegian households are dependent on direct electrical heating, the price of electricity is thought to be an important variable in explaining the demand for an electricity saving heating technology such as heat pumps. The higher the electricity price, the higher the demand for air-to-air heat pumps. The variable measures the annual average market price and grid costs to households, but does not include taxes. Real prices are used with 1998 as the base year. A one year lagged variable is also included, as well as a differenced variable for the error correction model. Data are obtained at Statistics Norway (2011c).

iv) Bank interest rate

According to traditional economic theory, the interest rate is a determinant of the profitability of an investment. A low interest rate triggers more investments, and could lead to higher demand for heat pumps. Data are obtained from Thomson Reuters (2011).

v) Previous heat pump sales

A central logic in the diffusion model is that the market needs a certain critical volume. This implies that the volume of sales last year could be an explanatory variable for the current year’s sales volume. This variable captures the market dynamics not explained by other variables, including effects due to changes in the price of the heat pumps. This price is not included in the model due to unavailability of data.

vi) Enova programs

To estimate the effect of Enova’s programs, we introduce two indicator variables in the ordinary time series regression models: one for the year 2003 (the first HSP) and one for the period 2006-2010 to represent the second HSP. We expect a clear positive effect of the 2003 variable. Also the 2006 variable is expected to be positive, but since air-to-air heat pumps are excluded from this subsidy, the size of this effect is expected to be lower.

We have estimated one optimistic and one conservative version of this model, using different types of intervention functions (Enders, 2004). The optimistic version models the effect of the 2003 HSP as a jump function, that is an extension of the 2003 indicator to cover also 2004 and 2005. This is to model a hypothesized prolonged effect of the 2003 HSP. The conservative version models the effect as a pulse function, meaning that the 2003 HSP made an impact only in 2003. The HSP reintroduction in 2006 is modeled as a pure jump function, with a lasting impact in 2006-2010.

The error correction model is based on a combined indicator for the Enova programs, and is estimated using one variable for the lagged indicator and one variable for the differenced indicator.

Baseline Estimation results

We now have three fundamentally different approaches to estimation of the baseline heat pump sales. The expert's assessment and comparison with the market development in Sweden during the same period represent relatively straightforward estimates. The three econometric approaches give results that differ somewhat, as illustrated in Figure 3. Among these three models, we choose as the best alternative for discussion the "conservative" model. It has the most logical specification of the 2003 HSP, it includes a dynamic element in terms of the lagged sales variable, and it has the most desirable values for test statistics relating to model misspecification and autoregression. Limited space prohibits a more comprehensive discussion of the econometric analyses[1].

The results of the estimation of the conservative model are shown in Table 1 below. All explanatory variables described above were entered, but only the variables remaining significant after the backward estimation procedure are presented in the table. The model has high explanatory power with a limited number of variables, the signs of all coefficient estimates are as expected, and it appears robust relative to autocorrelation and misspecification tests.

Table 1: Regression analysis for "Annual sales of air-to-air heat pumps". Conservative model.

Variable	Coeff. estimate	Std. error	t-value	Significance
(Constant)	-58 085	11 492.79	-5.054	0.000
Electricity price	1 392	255.44	5.450	0.000
ENOVA03 (pulse)	15 353	6 353.00	2.417	0.031
ENOVA06-10 (jump)	31 132	4 861.93	6.403	0.000
Previous year's sales	0.312	0.077	4.055	0.001

Adj. R^2 = 0.981
Durbin-Watson = 1.986
RESET23: $F(2,11)$ = 0.603, p = 0.565

We note that the electricity price has significant explanatory power on the demand for air-to-air heat pumps. A higher electricity price translates into higher heat pump sales, as expected. Further, the lagged (last year's) sales number also has significant effect on the market, i.e. high sales one year tend to spill over into the next year also. This finding is interesting with respect to the diffusion theory, since it indicates that an increasing sales volume is a market driver in itself. This variable perhaps also is related to the development of the price for heat pumps, a developing market with higher volumes may invite more competition on the supply side, thus causing a downward pressure on prices. However, due to lack of data, effects due to heat pump prices are not explicitly modeled in this analysis.

Both Enova-variables turn out with statistically and numerically significant values. The market effect of the 2003 subsidy program to air-to-air heat pumps is estimated to 15 300 units. Even more interesting is the fact that also the 2006 HSP shows a strong positive effect on the market for air-to-air heat pumps, even though this technology was not included in the 2006 HSP. This supports the findings from evaluations of the HSP programs, where a majority of the program participants typically report that they most likely would have invested in a heat pump also in the absence of a subsidy program. This indicates that not only the economic incentive, but just as much the communications effect of the HSP, is important. A public agency "endorsing" the technology

[1] A more in-depth documentation of the econometric analyses can be obtained by contacting the authors.

through a subsidy scheme, supported by web, phone advice and heavy marketing, is an important effect by its own. The general heat pump technology is part of the 2006 HSP, even though air-to-air heat pumps are not.

In Figure 3 below we have drawn the baselines implied by the different analytical approaches. We use the five baselines as guidance in order to establish our final Enova baseline. Principles for choosing the final baseline are: i) We want a clean and simple baseline with a "functional form" resembling an S-shaped curve. ii) Both the expert assessment baseline and the country comparison baseline are quite low, and produce high sales values attributed to the HSP. We want to set a conservative ex-post baseline, thus we use these two baselines as lower bounds for our proposed baseline (the lower the baseline, the higher the result attributed to the HSP). iii) From the econometric models we use the high baseline from the conservative model as an upper bound for the proposed baseline. Based on these restrictions, we stipulate our proposed "Enova baseline" from 2002 until 2010, as illustrated in Figure 3. This baseline is used in the subsequent calculations to estimate the total energy savings effect from Enova's Household Subsidy Programs.

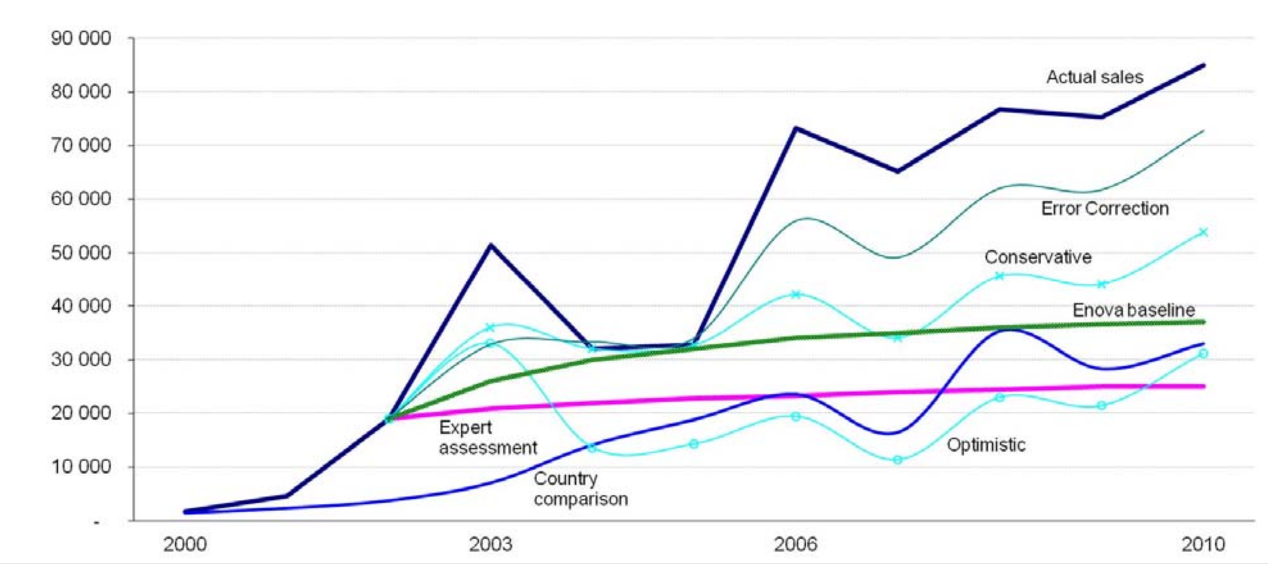

Figure 3. Baseline results: expert assessment, country comparison and estimated econometric models as basis for the Enova baseline (in green)

Estimated per unit savings

The difference between total sales and the Enova baseline is an estimate of the total effect of Enova's programs on the development of the market for air-to-air heat pumps, measured by the number of units diffused into the market. In order to calculate the energy savings from this technology we also need an estimate of the energy savings per unit. We choose to use the savings value obtained in the evaluation report of the 2003 Household Subsidy Program. This estimate is based on metered and temperature-corrected values for individual households, and therefore includes the real-life deviations from the technically "deemed" values caused by rebound, substitution and other user-related effects. For more details on the evaluation of the program, consult Bjørnstad *et al.* (2005).

For all households participating in the evaluation survey, the average annual savings was calculated as 5 116 kWh. For the purpose of this analysis we choose to use the conservative value of 5 000 kWh per household as our estimate of annual savings of electric energy from installation of air-to-air heat pumps in the Norwegian market.

Estimated energy savings from residential air-to-air heat pumps in Norway

The annual energy savings resulting from this program will grow over time as the number of units installed in households increases. Based on technical specifications of the heat pumps, we use 10 years as the useable life time of the average air-to-air heat pump. This means that all units installed after the 2003 HSP are assumed to still be in operation, and annual sales have added to the stock.

Based on our baseline and the total sales of air-to-air heat pumps in the 2002 – 2010 period, we infer that approximately 225 000 additional units are in operation in Norwegian households, compared to what would have been the case without the Enova programs. With annual saving per unit at 5 000 kWh this amounts to 1 125 GWh in added electricity savings in 2010 from the household subsidy programs.

Conclusions

We have demonstrated in this paper how the ”domestic-size” air-to-air heat pump has developed in the Norwegian market from a niche product with annual sales in the order of a couple of thousand units during the 1990s into a standard technology known to all and now found in almost one out of five households in the country. Average annual growth in sales during the ten year period from 2001 is close to 40 %. Our analysis further indicates that the aid from the national energy agency Enova has been crucial in this process, and the value of that intervention in terms of saved electric energy amounts to 1.1 TWh, or 3 % of annual household electricity use. Why this success?

The two other main technologies in the 2003 HSP did not show the same development, and the wood pellet technology, e.g., still has not crossed the “chasm” of the diffusion curve even after being part of both the 2003 and the 2006 (and onwards) Household Subsidy Program. This indicates that the heat pump technology has traits that households demand, such as ease of use, attractive economic performance/low cost, perhaps also some degree of technological “coolness”. We now see a development of the larger heat pumps (ground and air source pumps in hydronic heating systems) similar to that of the air-to-air systems, although in a smaller scale.

We have referred in the text to the evaluation of the 2003 HSP. On a question of whether or not the household participating in the program would have invested in the heat pump also in the absence of the subsidy, only 14 % answers “no”. In a retrospective context, a large majority of the households seems to be so satisfied with the technology that they could do without the subsidy. Our econometric analysis shows that also the 2006 HSP had a significant effect on the sales of air-to-air heat pumps, even though these heat pumps were not subsidized in the 2006 program. These two findings indicate that the marketing effect of both the 2003 and 2006 HSPs is perhaps more important than the subsidy per se. A subsidy program from a government agency, combined with a heavy marketing scheme, represents a powerful “endorsement” of the given technology.

The observed development of the air-to-air heat pump technology appears to be a “textbook” case of an application of the Enova model in Figure 1. The heat pump technology seems to have been ready for the Norwegian market, and vice versa, and only needed government subsidies, marketing, and reliable information to take off.

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