The beauty contest that nobody won – or how joint efforts brings high performance equipment to the market

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Abstract

A unique co-innovation process between housing manufacturers and manufacturers of heating and ventilation systems has led to the market introduction of new high-performance combined compact heating and ventilation systems for energy-efficient single family-houses in a Nordic climate. The background of the project was lack of adequate equipment on the market, a generally increased energy-efficiency awareness and stricter national energy-performance requirements.

The project started five years ago with a feasibility study initiated by the Swedish Energy Agency's innovation cluster and purchaser group for energy-efficient single-family houses, BeSmå. The purchaser group had identified a need for cost-efficient combined heating and ventilation systems for single-family houses with a low energy demand in a Nordic climate. Heat pumps and ventilation systems were readily available on the market, but they were over-sized with regards to installed power, needed too much space and were too costly. So BeSmå decided to stimulate manufacturers to deliver high-performance combined heating and ventilation systems.

Six tenders were received. Four of the tenders were very promising, but none of them achieved all of the technology procurement's mandatory requirements. Hence, no winner could be awarded. It appeared to be a beauty contest without a winner.

However, the BeSmå purchaser group saw the large value of the received proposals. The Swedish Energy Agency agreed to turn the project into a joint development project between housing manufacturers and equipment manufacturers, and this has led to the imminent market introduction of the new combined compact heating and ventilation systems.

This paper presents a market transformation project aiming at more energy-efficient single-family houses. It presents the process from identification of the need to the market introduction, including the potential for energy efficiency in the Swedish building stock and detailed information on the purchaser group's requirements.

Introduction

The general energy-efficiency awareness has increased among both manufacturers and buyers of single-family houses in Sweden during the last decade. The raised energy-efficiency awareness has to a large degree to do with the stricter national energy-performance requirements that has been introduced, but also other factors such as general awareness of climate change and environmental impact of energy production.

A market transformation is currently taking place. The increased awareness has led to an increasing demand on low-energy houses and passive houses, and it is almost impossible to meet the national building code's new

energy requirements for single family houses without installing a high-performance heat pump and a ventilation system with exhaust and supply air and heat recovery (ESX).[1]

When this project started in 2014 both heat pumps and ESX ventilation systems were readily available on the market. The problem was that the available products were oversized for low-energy houses This means that the available heat pumps and ventilation systems were designed for a larger energy demand than what is needed for a low-energy-house, and hence runs at a sub-optimal efficiency level. Furthermore, they were too bulky to be attractive for single-family house owners and producers. During the feasibility study we identified combined heating and ventilation products for low-energy houses for the German and Austrian markets, but these products were not possible to use in a Nordic climate. Hence, there was a lack of adequate equipment on the market, and a need for product development.

This need for development was identified by the participants of the Swedish innovation cluster BeSmå. The participants decided to carry out a feasibility study to see if technology procurement would be a suitable method to stimulate the required development. The feasibility study showed positive results, which led to a technology procurement. This was followed by a joint development project between equipment manufacturers and single-house manufacturers, and the desired products are now in 2019 ready for market introduction.

BeSmå is a Swedish innovation cluster and purchaser group for improved energy performance in both existing and new single-family houses. The cluster is jointly financed by the Swedish Energy Agency and housing and building component manufacturers. BeSmå aims at stimulating the realisation of a larger share of the untapped efficiency potential. The goal is market transformation through innovative processes and tools. The cluster's activities include feasibility studies, engineering, procurement, exchange of experience and demonstration projects.

Besmå's objectives are:

- Reducing heating and electricity demand in single-family houses, and thereby also reducing their greenhouse gas emissions.
- Developing methods and tools to remove barriers for a broad market introduction of energy-efficiency measures in the single-family homes sector
- Creating conditions for an earlier market introduction of energy efficient systems and products through network activities
- Creating the conditions for profitable energy efficiency while maintaining or improving the indoor environment.

Methodology

This project has been carried out in the following four steps:

- Feasibility study
- Technology procurement phase 1
- Technology procurement phase 2
- Joint development

Feasibility study

The feasibility study was conducted in 2014 within the BeSmå innovation cluster. The main driver for carrying out the study was the near zero energy requirement in the recast of the EU directive on energy performance of buildings (31/2010/EU), and the subsequent expected stricter energy requirements in the national building code.

The National Board of Housing, Building and Planning is responsible for the Swedish building codes. When this project started BBR19 was the building codes then in force. BBR19's energy requirement varied depending on geographical location and type of heating system. The minimum energy requirement was a maximum of 55, 75 or 95 kWh/m^2 for heating, ventilation, domestic tap water and other building related energy demand (not including household electricity) if the house was heated with electricity. The corresponding requirements for buildings using other heat sources was 90, 110 or 130 kWh/m^2. The BBR19 building code also included requirements on maximum electric power demand and average thermal heat losses for the building as a whole.

[1] An ESX ventilation system is a mechanical ventilation system with exhaust air (E), supply air (S) and heat recovery (exchange X).

The feasibility study concluded that a majority of all new Swedish single-family houses are heated with a heat pump and equipped with mechanical exhaust air ventilation. This was the most cost-effective solution for new single-family houses (villas, detached and semi-detached houses, one or two floors) to meet the minimum energy performance requirements of the national building code (BBR19) at the time.

The feasibility report also concluded that this solution will not meet the expected stricter building code requirements, and that many single-family house manufacturers already then (in 2014) produced houses with energy performance exceeding the building code minimum requirements.

A lot of different systems for heating and ventilation were available on the market. But none of them were adapted to neither the low energy demand nor the peak demand that occurs in low-energy buildings in a Nordic climate. The feasibility study found compact, combined systems for heating and ventilation with exhaust and supply air and heat recovery (ESX) developed for e.g. German and Austrian market, but none of the identified equipment were adapted for a Nordic climate.

Hence the BeSmå participants concluded that there was a need for development of compact, combined systems for heating and ventilation with exhaust and supply air and heat recovery (ESX) for low-energy houses in a Nordic climate. A development of such systems was seen as a necessity to be able to meet the new energy requirements in single-family houses in a cost-efficient manner.

The single-family house manufacturers who participated in the feasibility study expressed a special interest in solutions based on ground source heat pumps and ESX ventilation. Ground source heat pumps were preferred from aesthetic reasons since they do not require an outdoor unit, and due to the fact that they require a lower electric peak load than air-to-air heat pumps under Nordic climate conditions. They also expressed a strong interest in better communication between the heating and ventilation systems to ensure user-friendliness for the home buyer.

Technology procurement phase 1

Based on the feasibility study the BeSmå innovation cluster applied for co-financing from the Swedish Energy Agency for a technology procurement project. The aim of the project was to stimulate the market to develop products that meet the identified need of compact, combined systems for heating and ventilation with exhaust and supply air and heat recovery (ESX) for low-energy houses in a Nordic climate.

The Swedish Energy Agency approved the first part of the application in December 2014, which meant that the following tasks were performed:

- A purchaser group was formed and purchaser group meetings were held
- Tendering documents for the technology procurement, including the requirement specification, were developed
- Information and dissemination activities

The purchaser group consisted of representatives from five Swedish single-family house manufacturers, the Swedish single-family house manufacturers' trade organisation, one expert on heating and ventilation systems and project management.

The tendering documents were developed by the project management team and confirmed by the purchaser group. The requirement specification development was based fully on the single-house manufacturers' needs to ascertain that the new products will have a market when they are developed.

In a technology procurement it is of outmost importance to specify requirements that are possible to achieve, simultaneously stimulating the development of products with new functions or improved performance. In most technology procurements there are two kinds of requirements - mandatory requirements that have to be achieved, and desired requirements that add value to the tender if they are achieved. Both mandatory and desired requirements should be expressed as functions, in order to give the tenderer flexibility to develop the optimal and most cost-efficient product. In a technology procurement it is also important that the request for proposals in detail specify how the tenders will be evaluated.

Dissemination activities in this phase of the project included written articles in trade press, and project presentations at conferences.

The results from this first phase of the technology procurement was reported to the Swedish Energy Agency in October 2015. At the same time the BeSmå innovation cluster applied for co-financing for carrying out the remaining parts of the technology procurement.

Technology procurement phase 2

The Swedish Energy Agency approved the technology procurement phase 2 application in December 2015, which meant that the project could almost seamlessly continue.

This part of the technology procurement included the following tasks:

- Confirmation of the requirement specification and the other tendering documents
- Publication of the technology procurement
- Evaluation of tenders
- Procurement group meetings
- Dissemination activities

The preliminary tendering documents were reviewed, and after some minor changes they were confirmed as the final procurement documents by the purchaser group. The final documents were translated to English, to ensure possible participation from companies from all countries.

The technology procurement was then published in the EU Commission Official Journal. It was also announced in articles in trade press, at energy-related seminars, and at the single-family house manufacturers' yearly conference. The technology procurement allowed individual companies as well as consortia to submit tenders, and it allowed the equipment manufacturers a development phase of 6 months. This is a normal length of the development period in a technology procurement project.

At the final day for tender submission six tenders had been received. Four of the tenders were of very high quality with a high degree of innovation, and they were very close to fulfil all of the mandatory requirements.

Since none of the tenders fulfilled all the mandatory requirements no winner could be awarded. The purchaser group therefore decided to cancel the technology procurement, and BeSmå decided to ask the Swedish Energy Agency if they could agree to converting the project into a joint development project instead, with manufacturers of heating and ventilation equipment, manufacturers and experts.

BeSmå reported the results from the technology procurement phase 2 to the Swedish Energy Agency and applied for the project conversion in November 2016. In December the Energy Agency approved the project conversion.

Joint technology development

The joint technology development was carried out between December 2016 and December 2018, and it was based on the results from the previous technology procurement, phase 1 and 2. The joint project included the same five single family houses manufacturers as the previous technology procurement phases. and five manufacturers of heating and ventilation equipment. These five are the manufacturers who submitted the four promising and innovative tenders in the technology procurement[2].

The following tasks were included in the joint technology development project:

- Renewed review of the requirement specification for the desired product
- Purchaser group meetings
- Individual meetings with the heating and ventilation systems manufacturers to identify needs for support
- Creation of five working groups, all of them with close cooperation between one of the heating and ventilation systems manufacturer and two of the single-family house manufacturers
- Joint meetings with all of the heating and ventilation systems manufacturers and single-family house manufacturers
- Capacity building through workshops
- Dissemination activities - papers, seminars and website information
- Analysis of the performance of the new products

This project phase started with a new review of the requirement specification, carried out by the project management team, the purchaser group and the project expert. The review led to some minor changes. Some of the wording of the specification were corrected for, to meet new standards that have been implemented since the requirement specification was originally developed.

The project team then invited the five companies who had submitted the tenders that met almost all of the mandatory requirements of the technology procurement section for individual discussions. The purpose of these

[2] One of the tenders was submitted by a consortium, but the two consortium partners decided to work individually in this joint development project.

meetings was to discuss the performance of the equipment solutions the manufacturers had proposed during the technology procurement, to discuss how the new equipment could be further developed to meet all the mandatory requirements, and to identify the single-family house manufacturers' preferences of the proposed solutions.

The next step of the project was to form five subgroups, each group with one heating and ventilation systems manufacturer and two single-family house manufacturers. These groups held individual development meetings, and the aim of the meetings were both to stimulate the equipment manufacturers' product development pace and to anchor the developments with the single house manufacturers.

Several development meetings where all of the equipment and housing manufacturers participated were also held. In addition, three joint capacity-building workshops were arranged for all the working groups. These workshops focussed on the mandatory technology procurement requirements that none of the bidders had fulfilled – namely high-performance filters for ventilation systems, environmental declaration of building components and installations, and energy simulations. These three areas had been identified as common challenges for all of the manufacturers during the previous project phase.

The results from this joint development project have been disseminated through articles in trade papers, presentations at the innovation cluster BeSmå's annual conference, the single-family house manufacturers' yearly conference, and through BeSmå's webinars. Results have also been disseminated through the single-family house manufacturers' and equipment manufacturers' other channels.

Requirement specification

The technology procurement requirements were designated as either mandatory requirements or desired features. The mandatory requirements were minimum requirements that had to be met for the tender to be accepted. Compliance with the desired features was not mandatory, but would score positively during the evaluation. The requirements were divided in general requirements and function specific requirements.[3]

General requirements

The following general requirements and requested features were expressed:

- The unit shall include a supply and extract air module with heat recovery
- The unit shall include a heat pump
- At an outdoor temperature of –15°C:
  - The mandatory supply air temperature is at least 13°C
  - The desired supply air temperature is at least 16.5°C
- Compliance with all of the Swedish Building Regulation's (BBR current version) functional requirements relating to the heating and ventilation is mandatory
- The materials used must have good durability. For the purpose of this procurement, this meant that the materials should be assessed with reference to either the Sunda Hus [Healthy House] or Byggvarubedömningen [Building Materials Assessment] assessment systems.
- The unit should be built so that it is easy to install, maintain and replace.
- The unit should be a plug-in device
- Requirements regarding the size of the unit:
  - Mandatory requirement: Width maximum of 1.2 m, depth maximum of 0.6 m, height maximum of 2.0 m
  - Desired feature: Width: maximum of 0.6 m
  - If additional space is required behind or beside what stated above, this should also be reported
- The unit must have a setting for adjustable, balanced ventilation flows
- The guaranteed maximum price for the next two years must be specified and begin from the tender submission deadline date

Function specific requirements

The purchasers group also expressed functional requirements divided in the following six different categories.

[3] The full requirement specification can be reached at: http://energieffektivasmahus.se/wp-content/uploads/2018/01/Annex-A-Requirement-specification-2017-12-20.pdf

- Energy efficiency
  - Electrical power
  - Thermal efficiency/COP
  - Heat recovery
  - Heat pump coefficient of performance during heat recovery and heating
- Design
  - Study Design
  - Size
  - Heating power demand
- Operation and Maintenance
  - Operating and maintenance instructions in Swedish
  - Users' notes
  - Accessibility
  - Operational reliability
  - Periodic maintenance
  - Ease of replacement
- Robustness
  - Lifespan
  - Sustained energy recovery rate
  - Materials
- Health
  - Air quality
  - Noise
- Statement of costs
  - Present (savings - investment)

Results

The beauty contest that nobody won turned from a failure to a success story thanks to the persistence of the BeSmå's purchaser group and the manufacturers of heating and ventilation systems. No winner could be awarded in the technology procurement, but the technology procurement project was converted into a joint technical development project. The joint efforts in this project has resulted in five new compact, combined heating and ventilation systems for low-energy single-family houses in a Nordic climate. All of them have been developed based on the BeSmå project's requirements, in a dynamic process between manufacturers of heating and ventilation systems and single-family house manufacturers. The five new products vary slightly between each other, the most important differences are that some of them use ground source heat pumps and some of them use air-to-air heat pumps, and that they are using different refrigerants. These differences make a broader market uptake possible than what would have been the case with only one winner of the technology procurement project. One of the new products has already been introduced to the market, and the other four products are shortly to be introduced to the market.

Within the project, the calculated energy performance of the five new systems has been evaluated based on energy simulations. The evaluation shows that the new products can contribute significantly to improved energy performance in future single-family houses. Installation of these products will help new single-family houses to achieve the more stringent energy requirements of the Swedish building codes.

The newly developed heating and ventilation systems also have several positive side effects. The two most important of these benefits are improved indoor air quality and reduced electrical peak load demand compared to more established solutions with an exhaust-air heat pump and a mechanical ventilation system with merely exhaust air. The improved indoor air quality is achieved thanks to using a mechanical ventilation system with both exhaust and supply air with heat recovery. The reduced electrical peak load demand is achieved thanks to using a type of heat pump with a better energy performance, that the heat pump is sized to accommodate a low-energy house's demand more accurately, and a smart automation system allowing for demand flexibility (and shifting between heating demand, energy demand for ventilation, and energy demand for domestic tap water).

The project has also resulted in capacity building for both the equipment manufacturers and the single-house manufacturers, and knowledge sharing between them.

For all of the five new products large-scale testing is still needed to verify their long-term performance. Hence, BeSmå has sent an application to the National Energy Agency for co-financing of a verification project in situ.

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