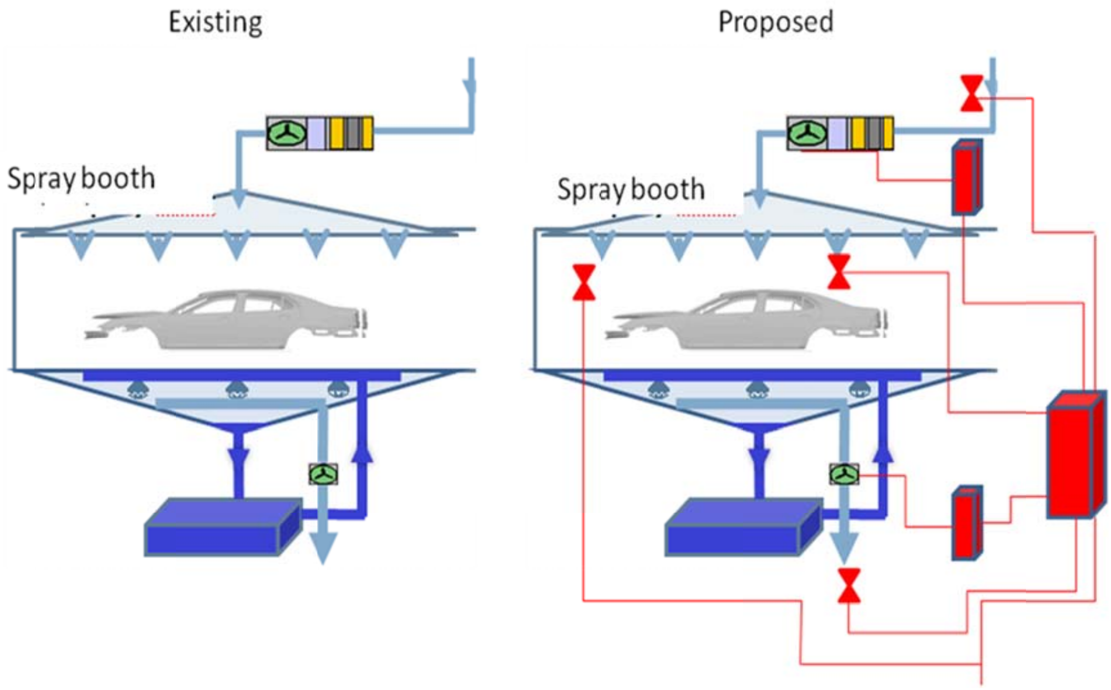
FFI

Energy Efficient Paintshop - EEM



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Project within: Sustainable Production Technology

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FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth.

FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**
For more information: www.vinnova.se/ffi

1. Executive summary

The overall goal was to gain experience from a full-scale demonstrator in Saab's paintshop with emphasis on energy saving in Swedish automotive paintshops. Paintshops are the largest consumers of energy in these factories. Experience would be collected through both practical experiments in a section of Saab's paintshop and by using theoretical models to develop optimized control strategies for this section of the plant. Other parties have been all in Sweden acting major vehicle paintshop, i.e. Pininfarina, Scania, Volvo Cars and Volvo Group. In order to control the large energy consuming fans and pumps frequency converters were installed, and to measure important parameters some sensors were also installed. Midroc performed the major installation of the converters in collaboration with Saab. In addition, the University West installed a data acquisition system for the collection of data from the production system. The drives have been used to reduce power consumption during operation, while the air pressure conditions and temperatures were logged and analysed. These initial experiments had two purposes - first, to make an initial assessment if the varuing operating conditions would be acceptable in terms of quality and also to validate the first theoretical models of the ventilation system. When the next step in the process should be carried out, i.e. in more detail validate the models, production stopped (April 2011) and has subsequently not been started. After bankruptcy, the project partners wanted to continue to exchange experience, and two workshops showed that considerable energy savings could be obtained in the paintshops that are in operation.
In summary,

- "Painting parties" gained insight into the possibilities of reducing energy consumption and environmental impact
- Equipment provider gained new experience of installing energy-saving components in the existing facility
- Research providers gained new experience in the modelling of a plant, which is in great need of energy saving measures. These models would be used to fine-tune the control equipment for power savings, but this part could not be implemented in Saab's full-scale demonstrator. In addition, the data collected during the initial stage verified that large energy savings could be achieved
- A scientific study was presented at a ventilation conference
- An experience document is jointly produced

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2. Background

The background is that automotive paintshops account for most of the energy consumption in the Swedish automotive plants, which is why ideas have been raised on the possibility of reducing the consumption. Vehicle paintshops are traditionally conservative and are run normally in full(nominal) mode even if there are long intervals between incoming bodies. The reason is that you do not want to jeopardize air balance between the different sections of the paintshop. To find out how much you can vary the air flow between the bodies while maintaining quality Saab offered to let a section of its paintshop for the full-scale experiments. Other vehicles paintings were clearly positive for this offer.

Supplementary Information 1

To implement a full-scale project involving control of energy consuming devices in an existing facility requires extensive additional investments. The main costly equipment is frequency converters to control power to the equipment in a controlled manner. To analyse the effect of such control actions also additional sensors are needed. In the project application phase Vinnova was reluctant to such a large equipment investment, which led to negotiations primarily with Saab. Saab in turn negotiated with Midroc, who installed most of the expensive components. See idea of supplementing in Figure 1.

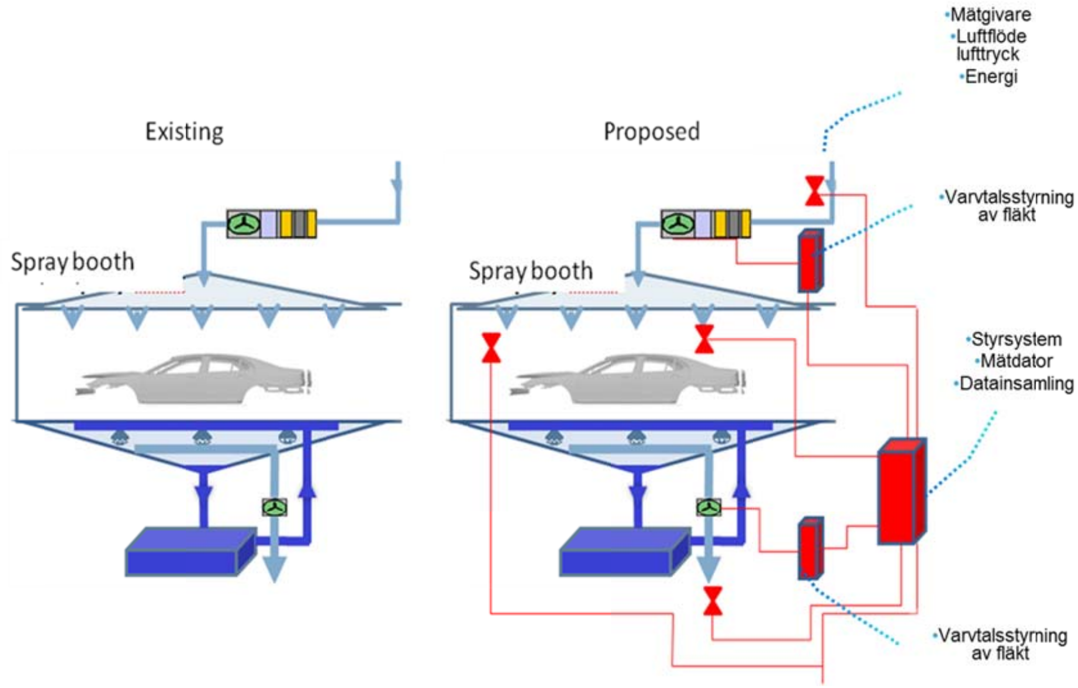

Figure 1 Illustration of the supplementary equipment

Supplementary Information 2

During the project, the project leader Saab went into bankruptcy, which implied a modified continuation: The Project Dnr 2009-02832 was replaced by Dnr 2011-03667, where due modifications were agreed by Vinnova. This was because the other partners wanted a continuation. This report considers the joint project.

Snap shop project facts – from application

Total budget	13.912.200 SEK
Project period	2010-01-01 (decision 2010-03-18) to 2011-12-31 (modified to 2012-12-31)
Grant from Vinnova	5.459.700 SEK (39% of total budget)
Vinnova Dnr	2009-02832 and 2011-03667
Project leader	Magnus Johansson, Saab Automobile Replaced by Anna-Karin Christiansson (HV) after Saab's bankruptcy
Researchers	Linköping University: Patrik Rohdin (industri ventilation) and Johan Löfberg (control) University West: Mattias Ottosson , Anna-Karin Christiansson

Partners

The partners represent three main areas of interest:

- Industrial end users: Pininfarina, Saab Automobile (project lead from start), Scania CV, Volvo Cars, AB Volvo
- Supplier and implementer: MIDROC Electro AB
- Academic and disseminating actors: Linköping University, University West and Innovatum AB

3. Objectives

The project had both scientific and industrial objectives:

Scientific Objectives

The academic objectives were set at project start to

- Develop a CFD-model of the selected section of the paintshop
- Validate the model through full scale experiments in the paintshop. From that conclude which areas to emphasise on with aim to reduce energy consumption while maintaining paint quality
- Implement a data acquisition system to monitor relevant properties in the plant
- Translate the CFD-model into a Model Predictive Control model with the objectives to minimise the energy consumption. This part could not be fulfilled
- Further scientific qualification of the researchers

Industrial objectives

The industrial objectives were set at project start to

- Increased knowledge how the air flow can be allowed to vary in the selected plant section without violating the paint quality
- Increased exchange of experiences between the Swedish paintshops related to energy savings
- Increased knowledge on how modelling of a plant can be used for optimising the plant operation

4. Project realization

The work was partitioned into work packages according to the following table showing responsibility and expected outputs:

Work package	Responsibility	Expected results
WP1: Preparing for research Development of a generic CFD model	**LiU**/Saab	CFD model
WP2: Ordering and installation of hardware equipment for control and measurements	**Midroc**/Saab /HV	The supplements needed in the plant to facilitate for control installed and verified
WP3: research activities; validating the CFD-model; simulation-based selection of up/down ramping strategies Development of an MPC-controller (not performed)	**LiU**/Midroc/Saab/HV	Experience from energy savings MPC-control strategy (not performed) Conference paper
WP4: Project handling	Saab/all	Meeting minutes, dissemination, follow up

Magnus Johansson,Saab, was initially the project leader. He was replaced by Anna-Karin Christiansson, University West, after the bankruptcy. Lars Anger, Innovatum chaired the steering group and was responsible for the economic reporting during the whole project.

5. Results and deliverables

The main results are briefly summarised:

Supplementing hardware

The installation of supplementary equipment was made for the plant section ”Täckfärg B” according to Figure 2. The supplements are shown in red/cyan. The installation was performed by Midroc in cooperation with Saab engineers.

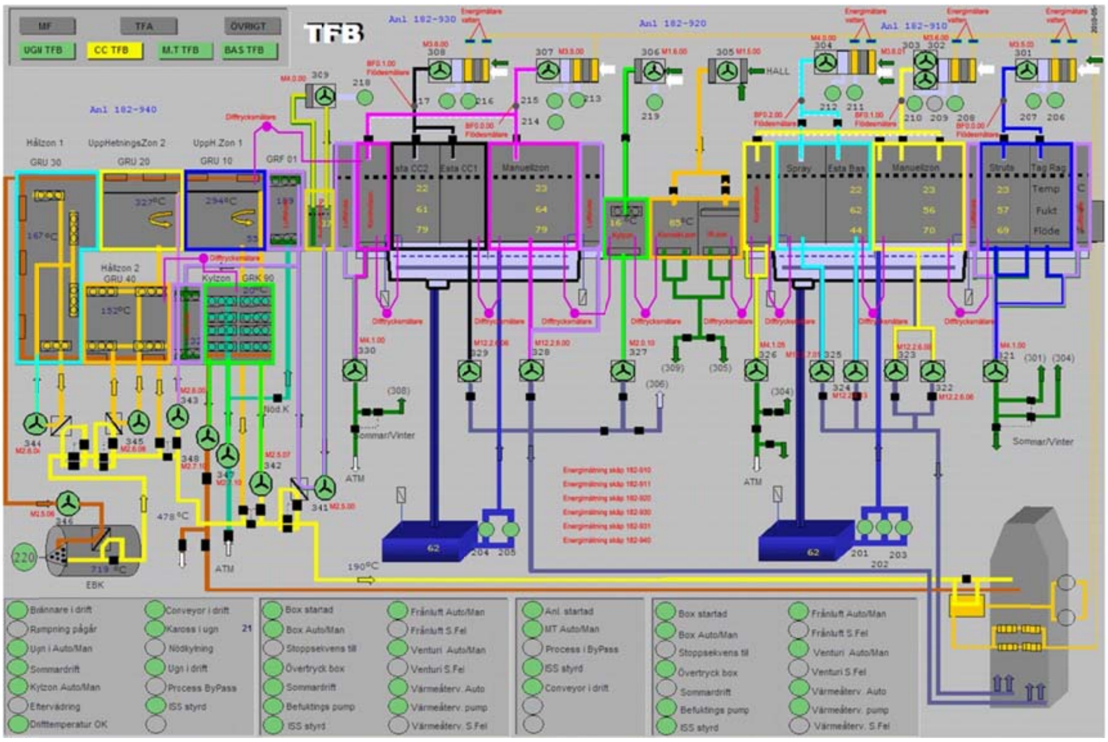

Figure 2 The Täckfärg B-section. The project supplements are shown in red/cyan

Supplementing measurement and control system

In order to be able to control the fans and pumps individually or in groups a PLC-system was employed. The architecture for sensor inputs and actuator outputs to the frequency converters are shown in Figure 3. This structure facilitated for storage of large amounts of data for post analysis.

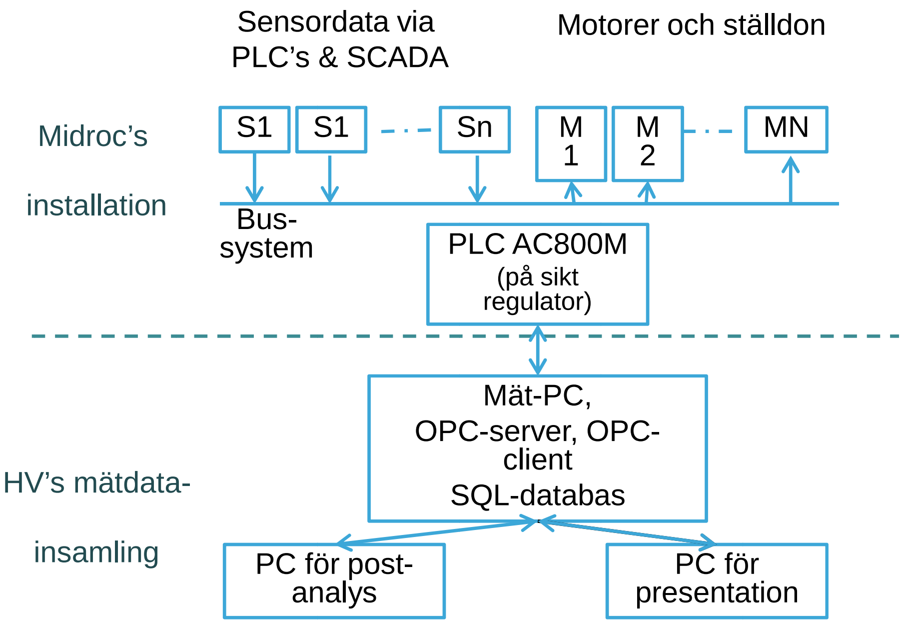

Figure 3 Structure for the data acquisition and control

Analysis of measurement data

Some fans were controlled to reduced power by means of the frequency converters, see Table 1. A lower rotary speed implies lower operating power consumption according to the table. The calculations on savings in the table are based on the assumption of equal time at nominal and reduced power mode. This investigation was meant to indicate where continued efforts should be directed. The paint quality was not affected badly during these tests.

Table 1 Different power levels for selected fans (no translation of the names)

Fan nr.	Fan	Nom freq Hz	E-save freq Hz	Nom. power kW	Operating power kW	E-save power kW	Savings %
302	Uf02M01, Tilluftsfläkt man/kontrollzon basfärg	50	27,5	110	84	20	76
303	Uf02M02, Tilluftsfläkt man/kontrollzon basfärg	50	27,5	110	71	16	77
326	Uf20M06, Frånluftsfläkt kontrollzon basfärg	50	20	30	22	1,6	92
304	Uf03M01, Tilluftsfläkt esta/spraymate basfärg	50	35	90	45	16	64
305	Uf01M01, Tilluftsfläkt IR-zon/konvektion mellantork	50	25	45	25	3,5	86
306	Uf02M01, Tilluftsfläkt kylzon mellantork	50	25	45	30	4,1	86
307	Uf01M01, Tilluftsfläkt man/kontrollzon klarlack	50	27,5	160	105	24	77
330	Uf20M03, Frånluftsfläkt kontrollzon klarlack	50	29	30	19	4	78
308	Uf02M01, Tilluftsfläkt estazon klarlack	50	27,5	75	32	8	75
309	Uf03M01, Tilluftsfläkt dunstzon	50	30	22	16	4	75

In order to know the dynamics during switch from nominal to lower power some data was investigated, see **Error! Reference source not found.**, for two relevant fans. This kind of experiments are needed for all controlled objects before being subjected to control.

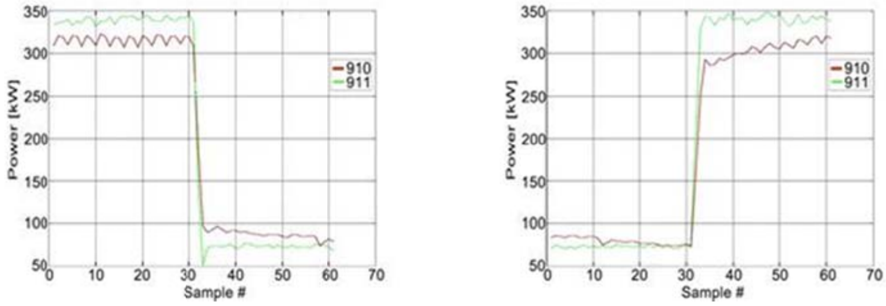

Figure 4 Switching between nominal and reduced power for two fans (Nr 910 and 911)

CFD modeling of the plant

In order to obtain more general knowledge of the possibilities to control the plant a CFD-model was developed by the researchers in Linköping. This is reported in the paper *Energy efficient process ventilation in paint shops in the car industry – experiences and evaluation of a full scale implementation at Saab Automobile in Swede*n. The paper was presented at the Ventilation Conference in Paris in fall 2012. In short it models the box geometry according to the structure in Figure 5.

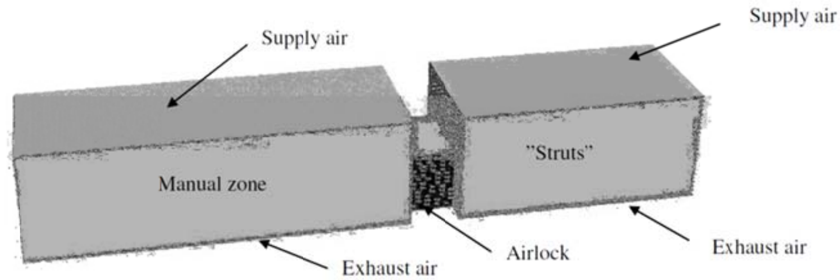

Figure 5 Box geometry used for modelling the air flows

Different equations are used for the flows during up- and down-ramping of the fans. Assuming conservation of mass, momentum and energy the air temperature and flow can be predicted. The flows are assumed to be transient, three-dimensional, non compressive and turbulent. Some simulation results show:

- Velocity distribution after 15 s =>
- If time between up- and downshift is less than 60 s, there will not be unacceptable flow bewteen the zones

Figure 6 shows a simulation output. For more details, see the conference paper.

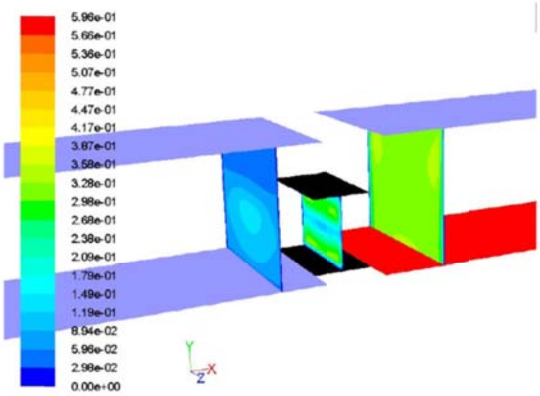

Figure 6 Simulation results obtained from part of the CFD-model

Delivery to FFI-goals

The main contributions towards the FFI-goals are

- Possibility to significantly reduce the CO2-footprint due to lower energy consumption
- Reduced cost through reduced power consumption, also leading to increased market
- Methods for more efficient energy savings at vehicle manufacture
- Increased cooperation between Swedish vehicle producers and with academy
- Increased R&D competence in Sweden

6. Dissemination and publications

Knowledge and results dissemination

The interest in the project has been immense from outside. Some links were presented in former status reports: (no guarantee that they are updated today)

- Cogent DataHub SuccessStories – http://www.cogentdatahub.com/SuccessStories.html
- Innovatum movie: http://www.innovatum.se/pages/default.asp?SectionID=2638&ArticleID=9532&ArticleGroup_projekt=
- Vinnova -http://www.vinnova.se/sv/ffi/Nyheter/2010/Energieffektivt-maleri-i-framtidens-fordonsfabriker/
- NyTeknik - http://www.nyteknik.se/nyheter/automation/verkstadsautomation/article2504181.ece
- Automotivesweden - http://www.automotivesweden.com/aktiviteterochnyheter/artiklar/svenskakarosstillverkareskaminskaenergiforbrukning.5.1baaf91291181a97f8000860.html
- Midrocelekto - http://midrocelectro.se/sv/Nyheter/Nyhetsarkiv/Energieffektivt-maleri-i-framtidens-fordonsfabriker.aspx

- IndustriKanalen - http://www.industrikanalen.se/fordonsindustri/midroc-bidrar-till-energieffektivt-maleri-i-framtidens-fordonsfabriker.aspx
- Metal Supply - http://www.metal-supply.se/article/view/49517/sveriges_karosstillverkare_i_gemensamt_projekt
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- Automotive Sweden - http://www.automotivesweden.com/aktiviteterochnyheter/artiklar/svenskakarosstillverkareskaminskaenergiforbrukning.5.1baaf91291181a97f8000860.html

Publications

Rohdin, P., M. Johansson, et al. (2012). Energy efficient process ventilation in paint shops in the car industry : Experiences and an evaluation of a full scale implementation at Saab Automobile in Sweden. Ventilation 2012**:** 1-6.

7. Conclusions and future research

Even if the full scale demonstrator could not be carried through in its full intentions, it was concluded that it is fully possible to reduce the power consumption in a vehicle paintshop without violating the paint quality – provided this is performed in a controlled manner. The partners have discussed this internally in their organisations and summarised according to:

Volvo Cars	-Has investigated possible implementation of a similar system in a repair box. Pay back not until after 5 years => Not intended for implementation today - Analysis how the plant is run today => Possible potential savings of at least 500kSEK/year without extra investments only through modified operations - Will consider the experiences from this project into new ones (exchange of an automatic box balancing system)
Scania CV	-Obtained knowledge that it is fairly simple and in practice possible to increase and reduce the flow of air in paint boxes with maintained air balance --even in zones without physical partitioning walls -- with limited settling time - ”Low speed mode” is installed in the new paintshop in Oskarshamn -- reduced speed of air flows when no car body is within the zone --Momentary profit: -700kW el, -560kW oil, -110kW cooling (however reduced heat recovery)

	-- -600SEK/h in low speed mode, approx 300-600kSEK/year -Will bring these experiences from demand-driven ventilation to all new ventilation projects
AB Volvo	-Obtained knowledge that it is fairly simple and in practice possible to increase and reduce the flow of air in paint boxes with maintained air balance --even in zones without physical partitioning walls -- with limited settling time- - AB Volvo operates a number of vehicle paintshop worldwide, which are upgraded and modified continuously. Also new paintboxes are designed. The experiences from this project will be spread within the company, and the awareness of the potential savings will lead to implementations later on. -Will bring these experiences from demand-driven ventilation to all new ventilation projects
Pininfarina	Refrain to comment, since this paintshop will be closed down
MIDROC	-It is of utmost importance to be involved early in the project - Always start the plant in full power mode so that the boxes are warm before entering the energy saving mode - 50 sec for transition between nominal and energy-saving mode => Also short timeslots between car bodies can be employed -The measurement-PLC was decoupled from the production system => Could easily be disconnected, if problems were encountered -Energy-saving mode could be employed during box cleaning without violating the working environment

Concerning research, both Linköping University and University West will bring the experiences further to new activities

8. Participating parties and contact person

Partner	Contact person
Saab	Magnus Johansson – före konkursen
LiU	Patrik Rohdin och Johan Löfberg
AB Volvo	Henrik Kloo
Volvo Cars	Jörg Wohner
Scania CV	Christer Bodén
Midroc	Joakim Ingemansson
HV	Mattias Ottosson och Anna-Karin Christiansson
Innovatum	Lars Anger
Pininfarina	Sven Kärrskog