VINNOVA Dnr: 2010-01338
Project manager: Birgitta Sjögren

Lean & Green Production Navigator – step 1

A pre-study has been carried out that contributes to a holistic approach for production teams integrating environmental work in production system development. The project has resulted in i) A methodology and a user guide for a green value stream mapping (Green VSM) ii) Work procedures for identification of essential environmental parameters to work with on a shop floor level (for production teams) including identification of relevant environmental parameters within 4 areas: heat treatment, surface treatment, machining and assembly, and iii) education material for integration of environmental aspects in production systems. The pre-study has also resulted in a suggested approach that links environmental work on a local level to overall environmental work, also from a life cycle perspective. The results serve as a platform for further development and research suggested in the FFI-proposal, Dnr 2010-02850. The results from the pre-study is available on the web-site www.leanresan.se.

Objective

The objective of the pre-study is to describe an approach for integration of environmental aspects in production system models and to create a common platform for further development and research within the area. This is described in a suggested approach in the FFI-proposal “Lean & Green Production Navigator, step 2”, Dnr 2010-02850. By consideration and integration of ecological, economical, and social/human aspects in production system models, this project contributes towards development of sustainable improvement and development work which is initiated both within and outside team areas/production teams.

Results and deliverables

The pre-study has resulted in following deliverables:

- Education material for integration of environmental aspects in development of production systems
  (See www.leanresan.se: Presentation material ”PPT”)
- Further development of a prototype methodology for an Environmental Value stream mapping (Green VSM) and development of a users-guide for practitioners
  (See www.leanresan.se: Overview ”A3” and presentation material ”PPT”)
- Procedure for identification of essential environmental parameters on a local shop floor level (for production teams) and identification of local environmental parameters at 4 types of work places (heat treatment, surface treatment, machining and assembly)
  (See www.leanresan.se: Overview ”A3” and presentation material”PPT”)
- Experience sharing between companies in an industrial workshop resulting in prioritized research- and development needs, also included in work packages in a proposed project proposal with additional industrial partners; Volvo Cars and Finnveden Gjutal
- The developed methods and approaches in the pre-study aims to contribute to increased knowledge and awareness of how environmental parameters can be integrated in the continuous improvement work in the case study areas. However, verification has not been possible due to the limited time period of the pre-study, but is planned to be performed in the suggested project proposal.

Project realization

The pre study was performed 1/9 2010 – 31/1 2011 in cooperation between AB Volvo (Volvo Technology AB), Swerea IVF, University of Skövde and Stockholm University.

The project's approach was to take a comprehensive approach to the environmental work at local level (for production teams in production) that is linked to overall environmental objectives and focus on both daily and long-term pro-active work from a lifecycle perspective. The pilot study also forms the platform for further development and research, as proposed in the FFI-application for the continuation project, Dnr 2010-02850.

Results from the pre study is published on the website ”www.leanresan.se”.

An industrial workshop has been held to disseminate knowledge and experience gained in the project. Project results were presented and development and research needs in the area were discussed. In addition to the participating partners in the project, were also Volvo Cars, Saab, ABB, SSAB, and representatives for FKG, Produktionslyftet and the FFI-project Green Production Systems (Dnr 2009-00975) invited.

1. Test and application of pilot method for environmental value stream mapping (Green VSM)

In the pre study a pilot method for Green VSM has been tested and validated in a robot cell at Volvo Trucks in Umeå. The pre study has built on the pilot method developed by previous case studies in Green VSM at Volvo. The case study has resulted in a compilation of resource usage at a typical robot cell and a user guide for how a Green VSM can be used locally at shop floor.

Value Stream Mapping (VSM) is often used in the Lean improvement work, but usually takes no account of environmental parameters. U.S. EPA has proposed to combine the VSM and environmental analysis to Green VSM. This has been tested and developed in case studies at Volvo. A Green VSM can be used to assess production improvements and environmental improvements "at the same time in the same tool”.
The goal is to develop Green VSM for use in manufacturing industry. The aim is to develop a method suitable to use in daily improvement work. It should combine production improvements with environmental improvements. The method should be applicable in various types of production.

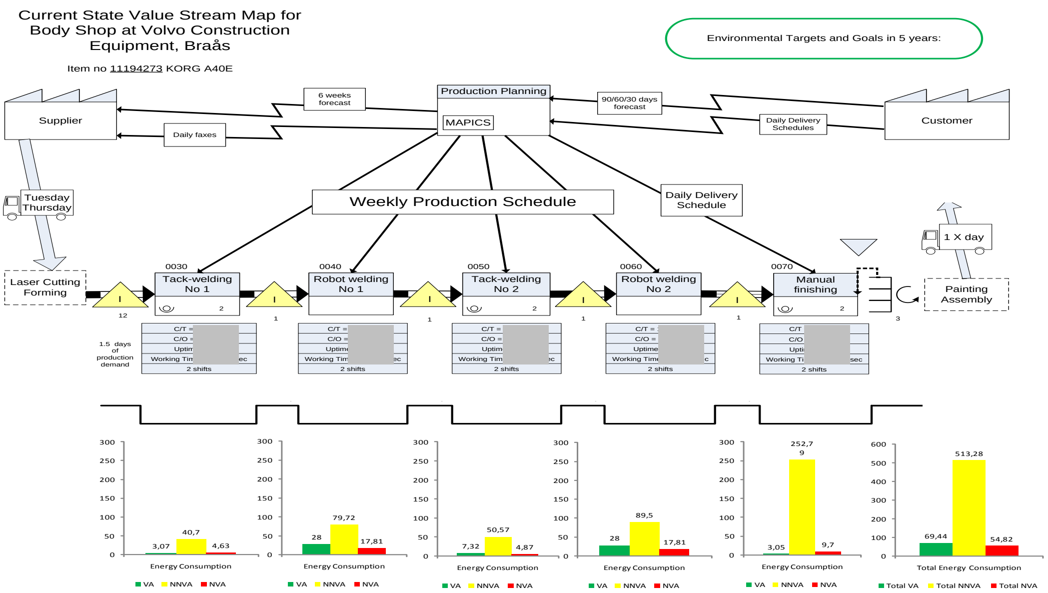

Figure 1. Example of Green VSM

Examples of Green VSM for welding production of Volvo CE Braås can be seen above. The focus of this study was the use of energy. The loss category model was defined with the following categories:

- Value-adding (VA) - direct energy for production equipment during active use, such as welding
- Necessary non-value adding (NNVA) - Energy for support systems such as lighting, ventilation, compressed air, etc., during production
- Non-value adding (NVA) - Idling of equipment, support systems energy usage outside production time

Case study Volvo Trucks Umeå

To test the method in production with high degree of automation, a robot cell in the new welding department at Volvo Trucks Umeå cab production was studied. The cell consists of three robots and welds parts of the roof of the cab. Data for energy use were collected and compared to the cell's production cycle, to detect unnecessary energy use.

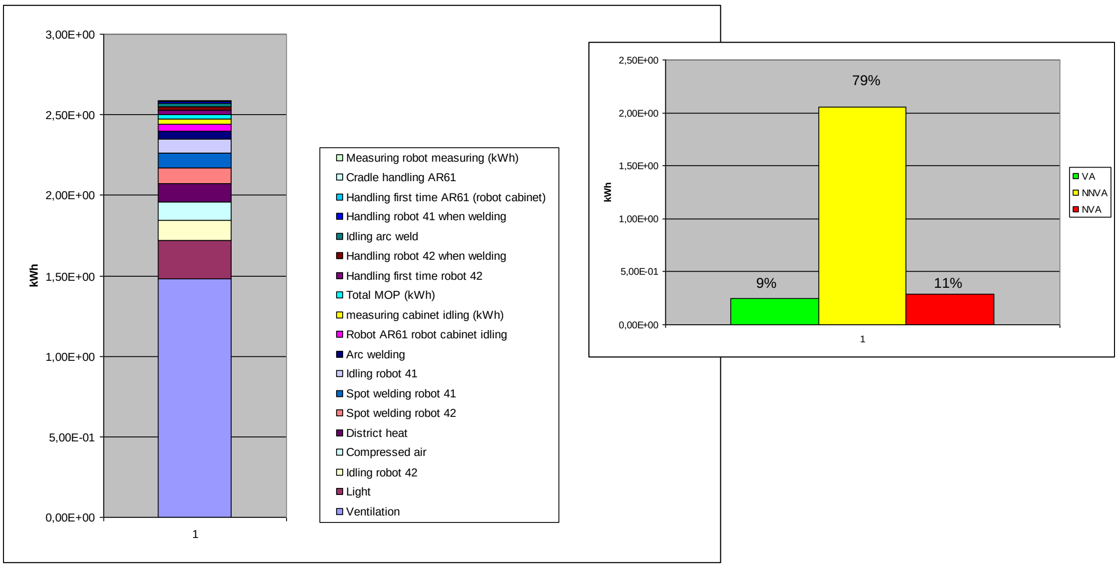

Figure 2. Energy use during a production cycle

The figure at left shows the energy consumed in a production cycle for Umeå robotic welding, including energy for production equipment, support systems (eg compressed air), and building support systems (lighting, ventilation). To the right, energy use is classified as VA, NVA, NNVA. The following activities were identified to have significant improvement potential:

- Idling on production equipment (11% NVA)
- Evaluation of the lighting and ventilation (long term perspective), which accounts for 57% of total energy use

Practical method for Green VSM

A practical method for Green VSM has been developed, with a proposal to work in teams with a three-step model:

1. Start of work and data collection
   - A short kick-off meeting held with the team to provide background and justification of environmental and production improvements. Responsibility for the team, goals and metrics are reviewed
   - Data collection starts with a "post-it" approach where the most resource-using equipment and support systems are identified. Data are collected for environmental and production parameters according to standardized templates (see below).
2. Compilation and analysis

   - Green VSM is compiled and resource / production data are categorized into: “value adding”, “necessary non-value adding” and “non-value adding”. Finished Green VSM is presented to the team and used in follow-up on the team board
3. Targets and follow-up
   - Goals are defined and environmental / production bottlenecks identified for improvement and follow-up.

Templates for data collection to simplify the work have been developed. Much of the data collected for a conventional VSM is also needed in the analysis of the green perspective, but some environmental data need to be added. Appendix 1 shows the data collection sheets.

<u>General conclusions Green VSM</u>
Using Green VSM provides an improved understanding of the production system, in terms of actions that affect productivity and / or environmental impacts. In the work of the "Lean & Green Production navigator" and the test cases at Volvo plants we saw specifically that:

- Green VSM provides a holistic view and a reduced risk of sub-optimization of environmental / production improvement
- The collection of both production and environmental data simultaneously will save time when collecting data, and simplifies the analysis (compared with the current situation where data collection and analysis is often done at different occasions, with different purposes and by staff with different skills)

<u>2. Relevant environmental parameters on a local shop floor level (for production teams)</u>

In the pre-study, local environmental parameters at 4 types of work places (heat treatment, surface treatment, machining and assembly) have been identified. Interviews were carried out with environmental coordinators, production engineers and industrial researchers with experiences of environmental work from several research projects. The issues in focus were “*What environmental parameters are essential for this specific work place/type of production”, ”What is needed to be considered to increase engagement of environmental work on a local shop floor level”,* and *“How can existing organization and leaderships support environmental work?”*

Surface treatment – Example of local environmental parameters essential for a work station for surface treatment are: Energy use, powder consumption, amount used paint, amount recirculated powder, amount cassation, efficiency, conveyer-capacity, cost and also the amount of carbon dioxide.

Heat treatment – Example of local environmental parameters essential for a work station for heat treatment are: Energy consumption (electric energy, gas, other), Amount used protective gas, Use of chemicals (detergents, heat treatment liquids), Amount cassation or rerunning and amount internal/external work

Machining – Example of local environmental parameters essential for a work station for machining are: utilization of process liquids, energy consumption during production and during down-time (stand by-losses), waste water and other waste (including specifically dangerous waste)

Assembly – Example of local environmental parameters essential for a work station for assembly are: handling waste, energy consumption in tools and supporting processes (e.g. pneumatic), reduction of spill and leakage, energy consumption during down time are parameters that are possible to influence within a team area. However, there are many factors that are decided and controlled outside the production team, for example in the purchasing processes and/or logistics which may effect e.g. the amount of packing material which may cause the amount of waste. Cross functional collaboration is therefore important to gain a holistic perspective.

This approach can be further developed to investigate in a structured way essential local environmental parameters for different types of production processes and work places. This may serve as a platform for environmental work in production teams linked to the company's overall environmental targets (see example table 1).

Surface treatment	Heat treatment	Machining	Assembly
Energy use Powder consumption Amount used paint Amount recirculated powder Amount cassation Efficiency Conveyer-capacity Cost Amount of carbon dioxide	Energy consumption (Electric energy, gas, other) Amount used protective gas Use of chemicals (Detergents, heat treatment liquids) Amount cassation (rerunning) Amount internal7external work	Energy consumption during production and during down-time (stand by-losses) Utilization of process liquids Waste water and other waste (including specifically dangerous waste)	Energy consumption in tools and supporting processes (pneumatic) Energy consumption during down time Handling waste Reduction of spill and leakage

Table 1. Example of local environmental parameters at workplaces with different types of production processes

The work procedure used in the pre-study to identify essential environmental parameters on a local shop floor level, is also useful and a result of the pre-study.

By interviews with environmental coordinators, production engineers and production personnel, essential environmental parameters can be identified from different perspectives. In a next step these can be a common platform to create an approach to link the local environmental work to the company's overall environmental work. Relevant issues in the interviews are:

- What is the current focus on environmental aspects – overall in the company, in this local work place?
- How is this work organized/performed?
- What environmental parameters are regarded today and how are they measured?
- How have these environmental parameters been identified and prioritized?
- What effects have been identified in this work?
- Which environmental parameters drive commitment?
- What is needed to be further developed?

Environmental investigations can also be used to analyze environmental impact in a structured way (By identification of inputs, outputs – identification of local environmental parameters – by setting improvement targets – following up) (Ref. Mall för miljöutredning – ett verktyg för att identifiera företagets miljöpåverkan (2002) M Zackrisson, G Bengtsson och C Norberg, IVF-skrift 02811). This approach is useful also to give feedback to personnel of performed improvements and other effects.

A conclusion of the pre-study is that it is important to identify local environmental parameters also from the production personnel's perspective and then link them to the company's overall environmental work and parameters within the plant/company. Cross functional collaboration also with suppliers is important both for the results and to increase participation in the improvement and development work. However, there are many factors that are decided and controlled outside the production team, for example in the purchasing processes and/or logistics which may effect e.g. the amount of packing material which may cause the amount of waste. Cross functional collaboration is therefore important to gain a holistic perspective.

3. Development of training materials for the integration of "green" aspects in production system Lean & Green

In the pre study has a training material been developed to illustrate how environmental work can be integrated in the development of production systems. The pre study has taken advantage of the experiences made within AB Volvo where Volvo Technology performs assessments of plants in a structured way according to their production system model VPS (Volvo Production System). In the pre study, a researcher with "environmental expertise" attended and studied the ways in which it is appropriate to integrate issues related to environment and energy.

The training material is developed to illustrate the interaction between good environmental standards and efficient production. It is based on the idea of seeing activities as (for the customer) value adding and non-value adding and establishes hence that environmental problems are most often caused by the inefficient use of resources (referred to as “waste of resources” or “muda”). For example, “muda” due to inefficient processes, disposable packages, energy consumption beyond the need to perform the operation, etc. The material describes how the 7 +1 wastes (“muda”) all contains elements of non-value adding environmental impact and the elimination of "muda" has the potential to simultaneously contribute to better environmental performance, if one is aware of the possibilities for synergies. The material also provides a number of examples, primarily from AB Volvo's facilities. It has been tested on a number of the plants at AB Volvo and has been very well received.

Project outcomes

In summary, this project contributes to approaches for:

- **Integration of the environmental perspective in daily work.** We do not just add environmental perspective on top of everything else that should be done but integrates it into the work with a lifecycle perspective
- **Further develop the production system models with "green" dimensions,** emphasizing resource efficient mindset
- **Focus on ways of working, employees' needs and skills related to environmental work.** This will improve the potential to affect earlier phases and to manage environmental issues within the business

The results from the pre study can be used both by

- Production units / improvement teams in larger companies and
- by small-and medium-sized enterprises (SMEs)

Participating parties and Contact persons

Birgitta Sjögren
AB Volvo
Birgitta.Sjogren@volvo.com
031-32 24 387

Lena Moestam Ahlström
AB Volvo
Lena.Moestam.Ahlstrom@volvo.com
031-3226191

Per Hanarp
AB Volvo
Per.Hanarp@volvo.com
031-3229249

Henrik Kloo
AB Volvo
Henrik.Kloo@volvo.com
031-3227099

Ulrika Harlin, industrial researcher
Swerea IVF
ulrika.harlin@swerea.se
031-706 60 54

Anna-Karin Jönbrink, industrial researcher, manager
Swerea IVF
Anna-Karin.Jonbrink@swerea.se
031-706 6126

Hans Lennart Norrblom, industrial researcher
Swerea IVF
Hans-Lennart.Norrblom@swerea.se
031-706 6192

Dan Högberg
Högskolan i Skövde
Dan.Hogberg@his.se
0500-448549

Gunnar Bäckstrand
Högskolan i Skövde
Gunnar.Backstrand@volvo.com
0500-474187

Ann Kjellberg
Stockholms Universitet
Ann.Kjellberg@ped.su.se
08-1207 6352

Publications and dissemination of results

Workshops

- Lean & Green Production Navigator – step 1 workshop; 25/10 2010
    - Presentation of results and identification of research and development needs

Conferences

- FFI-conference 19/10 2010
    - Poster to FFI-conference 19/10 2010

Netbased documentation

- www.leanresan.se
    - Documentation available on www.leanresan.se
        - Education material for integration of environmental aspects in development of production systems. (*Presentation material ”PPT”)*
        - Further development of a prototype methodology for an Environmental Value stream mapping (Green VSM) and development of a users-guide for practitioners. *(Overview ”A3” and presentation material”PPT”)*
        - Procedure for identification of essential environmental parameters on a local shop floor level (for production teams) and identification of local environmental parameters at 4 types of work places (heat treatment, surface treatment, machining and assembly), including 4 practical examples *(Overview ”A3” and presentation material”PPT”)*

Appendix 1 – Template Data collection sheets

VSM Data Collection

Responsible: Production engineer

1. Cycle time (C/T)	
2. Changeover time (C/O)	
3. Machine uptime	
4. No. of operators	
5. Working time	
6. Customer demand (Units)	

Note: 1. Based on the collected information, some other data could be calculated:

- Takt time = Available working time / Customer demands
- Non-working time = 8760 h – working time

Plant Data Collection

Responsible: Line manager

Plant Size		m^2

Line KPI's

Heating		$kWh/m^2 \cdot year$
Ventilation		$kWh/m^2 \cdot year$

Lighting		kW/m^2
Shift times		h/day

Station Data Collection

Responsible: Line operator

Station 1

Station Name and Size			
1.			m^2

Energy Consumption:

Equipment and energy consumption, both ON and STAND-BY					
Equipment Names	Equipment Power			Time/product	
1.	On		kW		h
	Stand-by		kW		h
2.	On		kW		h
	Stand-by		kW		h
3.	On		kW		h
	Stand-by		kW		h
4.	On		kW		h
	Stand-by		kW		h
5.	On		kW		h
	Stand-by		kW		h

Additional:

1. Is the equipment “ON” during non-production time?

Material Use:

Waste Types and how often the waste bins are changed				
Waste Names	Frequency		Weights of bins	
1.		/week		g
2.		/week		g
3.		/week		g
4.		/week		g