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Technology options in truck manufacturing: assessing whole-system eco-efficiency

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The EcoWater project was conducted by an international consortium coordinated by NTUA (National Technical University of Athens). IVL participated in the R & D work, in addition to leading one of the industrial case studies (Volvo Trucks), represented by Volvo Technology.

EcoWater ran 2011-2014. The project is presented in more detail on http://environ.chemeng.ntua.gr/ecoWater/
The project website holds a complete repository of all public deliverables from the EcoWater project.

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Technology options in truck manufacturing: assessing whole-system eco-efficiency

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Keywords: eco-efficiency, technology assessment, automotive industry, water use system, environmental impact, total value added, net economic output, multi-stakeholder interactions

Extended abstract

Background

Eco-innovation has been generally directed at energy input-substitutes, end-of-pipe emissions control, component recycling, etc. Some companies have made investments reducing resource burdens within the production process. Such eco-innovations aim to combine economic advantage with lower resource burdens. These improvements have been often assessed (and compared) as an eco-efficiency ratio within a production unit. Looking further, the FP7 EcoWater project has analyzed eco-efficiency on a whole-system level, i.e. among heterogeneous actors across the water value chain (i.e. the water use system including process-water users, water providers and wastewater treatment companies). The results presented here come from one of the eight EcoWater case studies, Automotive industry.

Aim

Along the lines of EcoWater, this study investigated technology options for whole-system eco-efficiency improvement in truck-cabin production at Volvo Trucks, which is serviced by companies for water abstraction and wastewater treatment. The study focused on two production sites, Umeå and Tuve in Sweden, which use water in corrosion-protection processes. Relative to its overall industrial sector, Volvo represents strong prospects for reducing resource burdens in water-use processes, especially from chemical inputs and wastewater. Such eco-innovations involve more complex interactions beyond the production site, so the options warrant a whole-system comparative assessment, whose flows are shown in Figure 1.

The results of a baseline assessment would indicate locations of possible economic and environmental improvements in the studied system and support the decision on appropriate technology options to study.

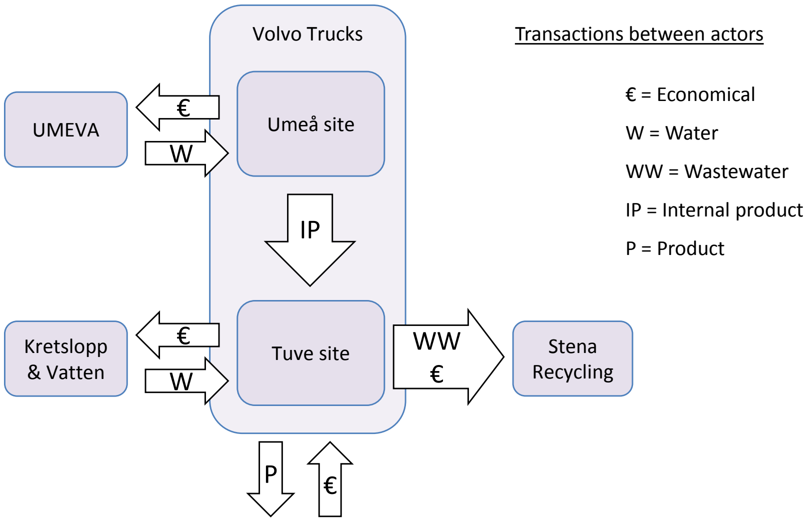

Figure 1: whole-system economic and resource flows

Method

After identification of the system boundaries and evaluation of the baseline, a modelling study assessed how different technology options would change the whole-system eco-efficiency, i.e. the ratio between total value added (TVA) and environmental impacts. The latter were assessed through standard mid-point indicators (JRC, 2011). Data came from the companies and from literature. Modelling was carried out in a toolbox developed in the EcoWater project (accessible from the project web-site http://environ.chemeng.ntua.gr/Ecowater).

Results

The water use system was mapped into four stages; water abstraction, water treatment, water use and wastewater treatment. The mapping shows that the industrial actor, Volvo Trucks, is involved in all four stages of the water use system while also relying on the service from three additional actors (Figure 2).

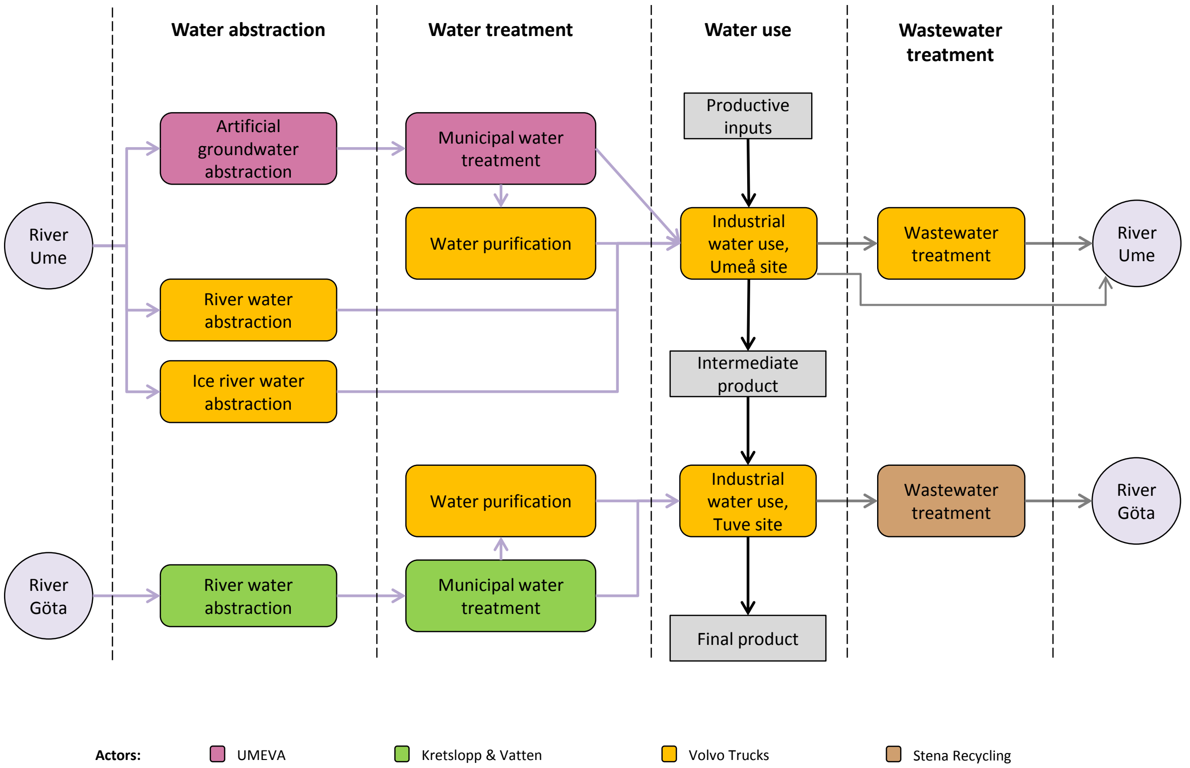

Figure 2. Water use system coloured by actor.

The baseline assessment showed that new technologies of highest interest are those that can be implemented at Volvo Trucks in order to either

- Reduce water use (which will also reduce use of electricity for pumping in the whole system),
- Reduce energy used for heating,
- Reduce the use of scarce elements in chemicals,
- Reduce the use of elements that become toxic pollutants in the wastewater, or
- Reduce the use of elements that become nutrients in the wastewater, causing eutrophication.

Four innovative technologies, contributing to one or more of the bullets above, were included in the study. In addition to an individual eco-efficiency evaluation of each technology, three technology scenarios were formulated from different combinations of technologies according to the following criteria:

- **Resource efficiency** – combination of technologies that has a positive effect on the consumption of resources (water, energy, scarce elements).
- **Pollution prevention** - combination of those technologies that has a positive effect on the emissions to water and air in the foreground (i.e. occurring at one of the facilities in the system, not due to upstream burdens from power generation or chemicals production). In this case there are no emissions to air in the foreground, so technologies were chosen solely on their potential to reduce water pollution.
- **Circular economy** - combination of those technologies that promote circular economy, in our case either use more district heating or result in an increased process-internal recirculation.

Table 1 presents a summary overview of the assessed technology options.

Table 1: Overview of technology options for assessment of eco-efficiency. Individual assessment, Resource efficiency scenario (RE), Pollution prevention scenario (PP) and Circular Economy scenario (CE).

Technology	Implemented at stage:	Assessment			
		Individual	RE	PP	CE
Silane-based surface treatment	Water use, Tuve	X	X	X	
Membrane distillation	Water treatment, Water purification, Tuve	X			
Membrane distillation	Water treatment, Water purification , Umeå	X		X	X
Electro-deionisation	Water use, Umeå	X			
Recirculation of process water and chemicals	Water use, Umeå	X	X	X	X

The results are not conclusive across the set of environmental indicators, i.e. they show both environmental improvement and impairment within the same technology evaluation. Some technology options improve whole-system eco-efficiency, but some offer only minimal improvements or impairment (Figure 3).

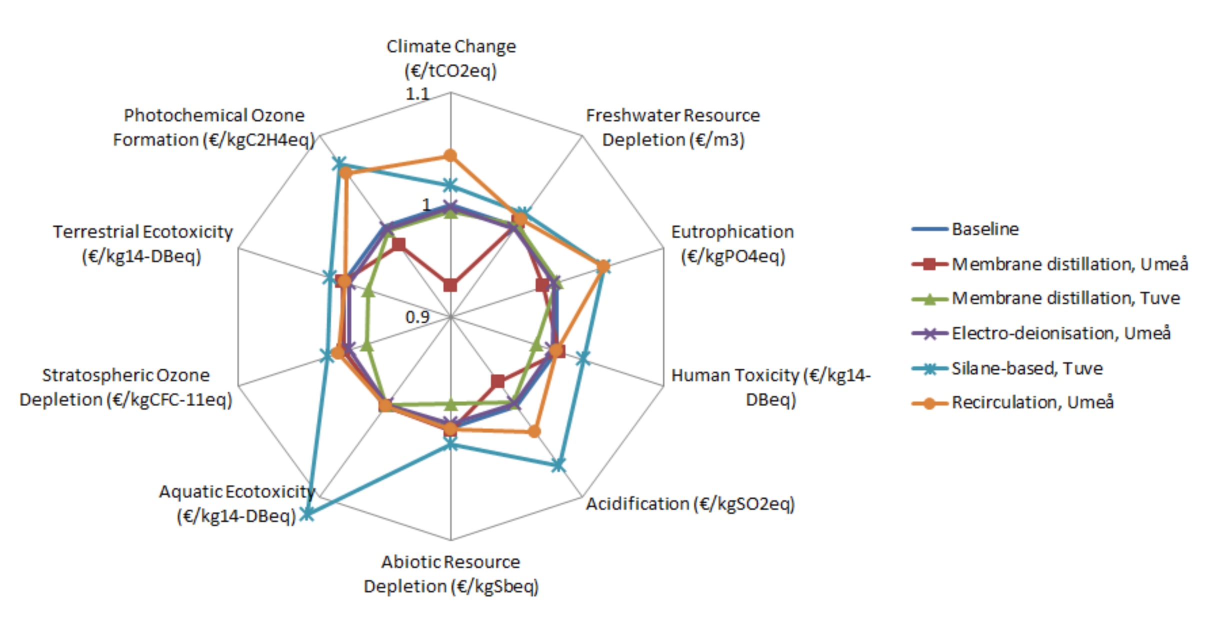

Figure 3. Individual technology eco-efficiency assessment. Baseline is scaled to 1 for all indicators.

The eco-efficiency assessment of technology scenarios shows that the scenarios on Resource efficiency and Pollution prevention are more favourable than the scenario on Circular economy (Figure 4).
For the Pollution prevention scenario the eco-efficiency was increased for all 10 indicators, some indicators increased by more than 10%.
For the Resource efficiency scenario the eco-efficiency was increased for 9 out of 10 indicators, some indicators increased by more than 10%. This scenario resulted in a decrease of approximately 3% in the Climate change indicator (€/tCO2eq). The latter was due to that one of the technologies caused an increase in electricity use, which in turn increases the CO2-emissions in the background system.
The scenario on Circular economy did not show as good results on eco-efficiency as the other two. Several indicators were unchanged compared to baseline, a few indicators increased by 2-4% and one indicator (Climate Change) decreased by about 4%.

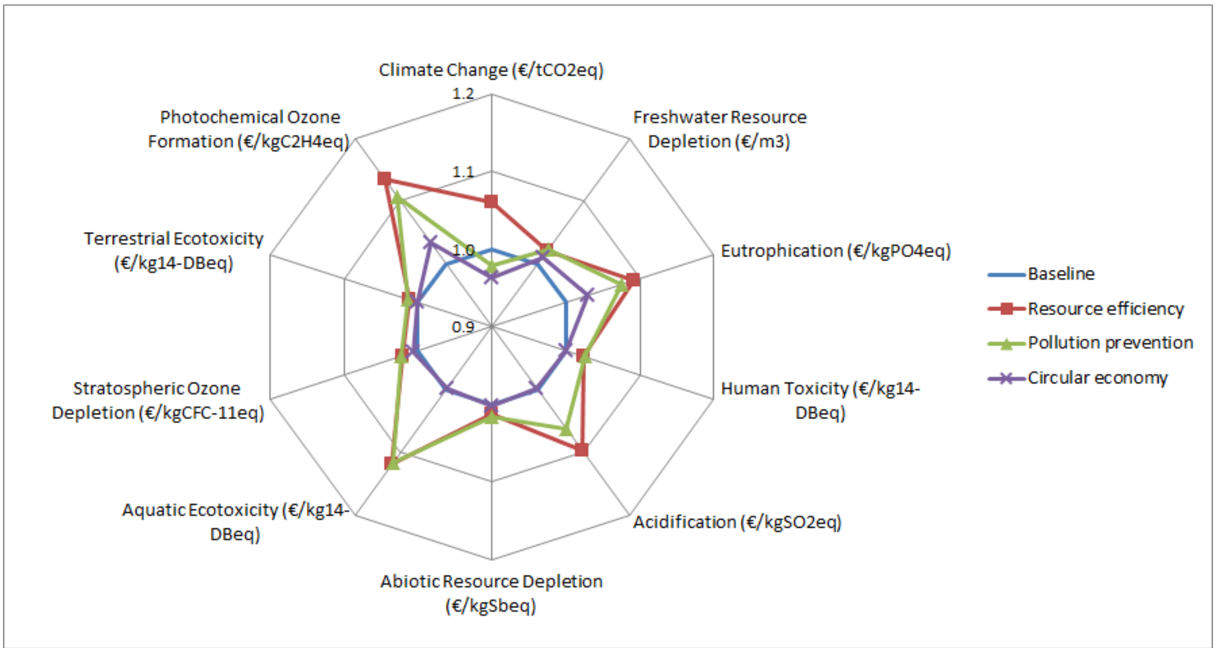

Figure 4. Technology scenario eco-efficiency assessment. Baseline is scaled to 1 for all indicators.

The change in TVA and net economic output per actor is different for the different technologies (Table 2). The results show options where the TVA would be redistributed across the whole-system value chain: the Tuve site would pay the water-supply company for less water and would pay the WWT company Stena for much less WW to treat. But for the system the TVA still increases. Other options result in a decreased TVA. However, the changes in TVA are small compared to the changes in environmental impact, so even with a decrease in TVA the resulting eco-efficiency is still higher than baseline for a number of technologies and technology scenarios (as was shown in Figure 3 and Figure 4). The relative change in economic and environmental contribution to the eco-efficiency ratio is exemplified for the indicators of Climate Change and Eutrophication (Figure 5). The other indicators result in similar patterns with respect to changes in economic and environmental performance.

Table 2. TVA and actors' net economic output per assessment compared to Baseline. Increase (+), decrease (-) or no change (=).

	TVA	UMEVA	Kretslopp och Vatten	Volvo Trucks	Stena Recycling
Baseline	~ 28 900 000	~ 20 000	~ 2 100	~ 28 700 000	~ 160 000
Technology scenario assessments					
Resource efficiency	+	=	-	+	-
Pollution prevention	-	-	-	+	-
Circular economy	-	-	=	-	=
Individual technology assessments					
Silane-based, Tuve	+	=	-	+	-
Membrane distillation, Tuve	-	=	-	-	=
Membrane distillation, Umeå	-	-	=	-	=
Electro-deionisation, Umeå	-	=	=	-	=
Recirculation, Umeå	-	=	=	-	=

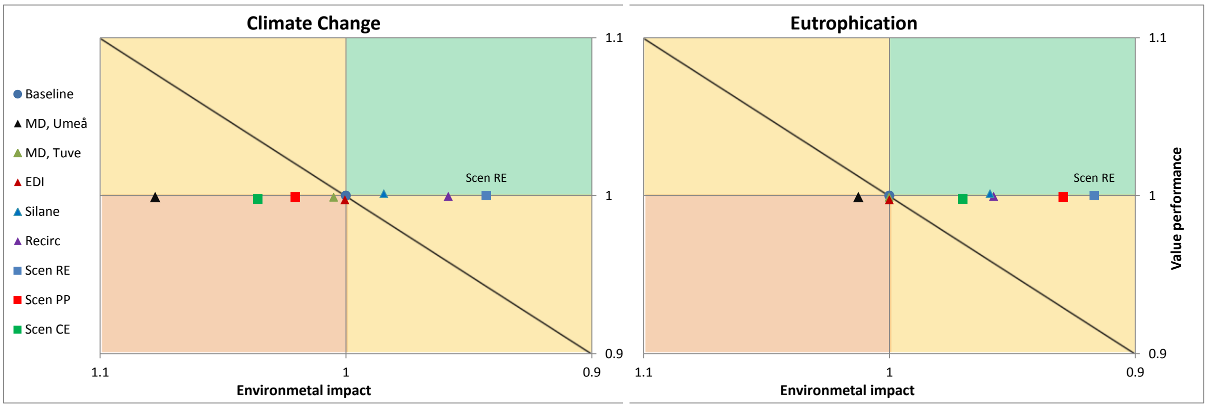

Figure 5. Economic and environmental performance of technology implementation. Climate change (left) and Eutrophication (right). Red area represents a decrease in both economic and environmental performance. Yellow areas represent an improvement in one but a weakening of the other. Green area is the eco-innovation zone, where there is an improvement in both economic and environmental performance.

Stakeholder interaction

The analyses provided a basis for two multi-stakeholder workshops to discuss how to optimize whole-system eco-efficiency and how to anticipate distributional effects. The workshops also drew on the PESTLE-scenario method to discuss drivers and barriers of such eco-innovations, how those factors may change in the future, and how companies could anticipate or influence such changes. The wastewater treatment company stressed the importance of stakeholder collaboration at an early stage of technology changes in industry. Discussions in the pre-implementation planning would highlight e.g. whether potential changes in waste and wastewater composition render a higher treatment service price. The methodology and tools developed in EcoWater can be very helpful in such discussions.

The outcome of the two workshops can be summarized as follows:

- The results of technology eco-efficiency assessment triggered discussions between stakeholders.
- The systemic view brought greater insight for stakeholders into
  - where the largest environmental and/or economical improvements can be made
  - that technology implementation could redistribute the economic outcome of the system
  - how stakeholders may influence each other within a common water use system

Conclusion

The eco-efficiency of a set of technologies and technology scenarios, applied in a defined system of interlinked actors, has been assessed by use of methodology developed in FP7 project EcoWater. The results of such assessment can be very useful to stimulate discussions between stakeholders.
This was proven at two multi-stakeholder workshops which gave the stakeholders greater insight into where the largest improvements can be made, both environmentally and economically, and how they may influence each other within a common water use system.

Two technology scenarios, resource efficiency and pollution prevention, seem particularly favourable for implementation in the studied system, due to their increase of eco-efficiency on practically all indicators. The fact that the increased eco-efficiency is mainly due to improved environmental impact and not increased TVA would imply that companies need strong incitements for investing in environmentally friendly technologies.

The EcoWater methodology provides a straightforward step-by-step framework on conducting eco-efficiency analysis of technology options in industrial applications. The difficulties in conducting the analysis have not been methodological but lay in the need for sufficiently accurate data on the industrial process and alternative technologies. Although modelling of the baseline situation can be time-consuming it is manageable, especially if the modelling team has a good communication with the stakeholders of the modelled system. In the study, it was sometimes difficult to get industrial process data on the desired level of detail, e.g. data representative of individual process sections rather than aggregated for the whole production unit.

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