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Process eco-innovation: assessing meso-level eco-efficiency in industrial water-service systems

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ABSTRACT

Eco-innovation combines economic advantage with lower ecological-resource burdens. Eco-innovation has been generally directed at energy input-substitutes, component recycling, etc. Some companies have made investments reducing resource burdens in the production process. This study investigated options for eco-efficiency improvement in two large manufacturing companies, Volvo and Arla Foods. Their impetus for eco-innovation comes from the companies' environmental policies, as well as from external drivers such as future higher costs and resource scarcity. Relative to their respective industrial sector, these companies represent strong prospects for reducing resource burdens in water-service 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.

The EcoWater project has analysed the entire water-service value chain through meso-level interactions among heterogeneous actors (process-water users, providers and wastewater treatment companies). The project has developed a methodology to obtain the necessary information, to involve stakeholders in the assessment and to facilitate their discussion on alternative options. Each study stimulated internal company discussions on the need and means to evaluate whole-system effects of investment decisions. Inter-organisational cooperation helped to anticipate how meso-level resource-efficiency relates to lower burdens in wastewater treatment.

The assessment method can be extended to any water-service system. By comparing options, the method can facilitate better decisions improving meso-level resource efficiency. As wider implications, some improvement options may complicate 'eco-innovation' as double-eco benefits: win–win for whom, where and what level?

1. Introduction: meso-level eco-efficiency

Eco-innovation encompasses various innovative practices combining economic and ecological-resource benefits. Commonplace examples have been renewable energy or (more recently) biomass as an input-substitute for fossil fuels. Going further, production-process upgrading has lowered resource burdens, e.g. by substituting less harmful chemical inputs, internally treating wastewater, reusing water and/or wastes, etc. Such improvements generate relatively greater changes beyond a specific production site, e.g. through its relation with a wastewater treatment plant.

To evaluate such improvement options, eco-efficiency denotes a ratio between economic benefits and ecological-resource burdens. This ratio helps to compare any current or future changes with a baseline. Eco-efficiency has been generally assessed in a micro-level system, e.g. at a specific site in a company's production processes. This focus neglects wider effects, warranting assessment at

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the *meso-level*, which has also been called the whole system. Some experts and practitioners have emphasised the need for such an assessment, encompassing the entire value chain of a production process, alongside shared responsibility for whole-system improvement. From an inter-organisational perspective, the whole-system or meso level can be defined as interactions among heterogeneous actors across the entire value chain (see Methods section).

This paper addresses two main questions:

- For whole-system effects on eco-efficiency, what methods can assess and compare eco-innovations?
- What is the role of inter-organisational cooperation in such comparisons?

These questions will be addressed through preliminary results of the EcoWater research project. As a literature survey, Section 2 explains the concepts of eco-innovation and its eco-efficiency assessment, as subsequently integrated in Section 3 on research methods. Then Sections 4 and 5 show how the project applied those methods and concepts in two case studies. On that basis, the conclusion answers the above question and suggests wider relevance.

2. Eco-efficiency through eco-innovation: analytical concepts

This section links analytical perspectives on eco-innovation and eco-efficiency, as a basis for the methodological novelty presented in the subsequent section on Methods.

2.1. Eco-innovation: forms and options

Eco-innovation encompasses various innovative practices which enhance resource efficiency by combining economic value with environmental performance (see Fig. 1). By combining such benefits, it has been widely seen as 'enabling win–win synergies' (OECD, 2012). But motives may be diverse and ambiguous. Cases can be distinguished 'where environmental motives are as important as (or less important than) economic motives'. Where the latter are most important, environmental improvements can be unintentional effects of investment decisions (Markusson, 2011: 300). Primarily economic motives may stimulate resource-efficiency improvements which incidentally reduce emissions (Clayton et al., 1999).

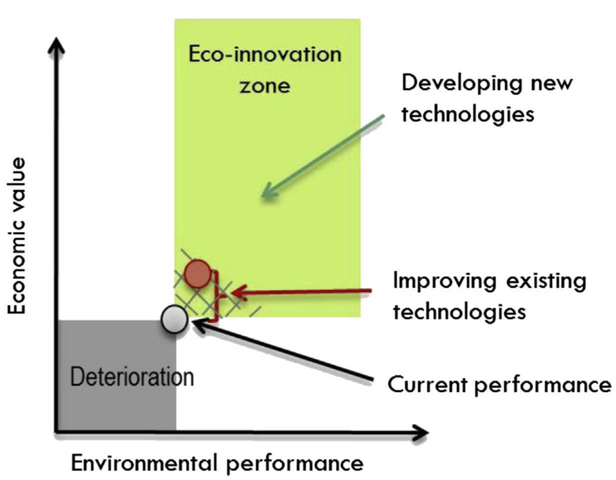

Fig. 1. Eco-innovation through new technologies (Credit: IVL).

Giving 'eco' a double meaning, eco-innovation has been defined more broadly as 'a change in economic activities that improves both the economic performance and the environmental performance of society' (Huppes et al., 2008: 29). According to the Europe INNOVA Panel on Eco-innovation:

> Eco-innovation means the creation of novel and competitively priced goods, processes, systems, services, and procedures that can satisfy human needs and bring quality of life to all people with a life-cycle-wide minimal use of natural resources (material including energy carriers, and surface area) per unit output, and a minimal release of toxic substances (quoted in Reid and Miedzinski, 2008: i).

According to most definitions, eco-innovation reduces the environmental impact caused by consumption and production activities, regardless of whether this is the main motivation. Taking many forms, eco-innovation varies from incremental eco-efficiency improvements to fundamental change replacing a system (Carrillo-Hermosilla et al., 2010: 1073–74). Towards the latter improvements, the European Commission has promoted an Integrated Product Policy, aiming to support the realisation of environmental product innovations which broadly reduce all environmental impacts throughout a product's life cycle. This has been conceptualized as 'integrated environmental product innovation' (Triebswetter and Wackerbauer, 2008). Innovation has several roles in resource efficiency (EIO, 2011b: 12).

Manufacturing industry has introduced such innovations, e.g. through water-efficient technologies reducing water demand and pollution. A closed-cycle process 'maximises the useful life of products and minimises the waste and loss of valuable and scarce metals' (Ayres and van der Lugt, 2011). Eco-innovation has been 'closing the loop' between water and energy management in a Cleaner Production perspective, e.g. through WW reuse: 'once-through cooling, where the water is used once for cooling and then directly is discharged, is replaced by closed-loop systems and cleaning-in-place (CIP) systems, where cascading is part of the cleaning process' (WssTP, 2013: 41).

Eco-innovation depends on parallel socio-institutional innovation, as academic studies have emphasised (Rennings, 2000). Accordingly, eco-innovation is understood more broadly than technologies:

> The scope of eco-innovation may go beyond the conventional organisational boundaries of the innovating organisation and involve broader social arrangements that trigger changes in existing socio-cultural norms and institutional structures (OECD, 2009: 2).

Eco-innovation is influenced by interactions among regulators, firms and other actors. Understanding such interactions is essential for facilitating eco-innovation (Del Río et al., 2010: 552). Indeed, inter-organisational cooperation can facilitate assessment of improvement options, as discussed next.

2.2. Eco-efficiency assessment: meso-level novelty

Various eco-innovations can be compared by assessing their relative eco-efficiency. According to a report from the European Environment Agency, 'eco-efficiency is a strategy or an approach aimed at de-coupling resource use and pollutant release from economic activity' (Mol and Gee, 1999: 24). To be operationalized, the concept denotes a quantifiable ratio between the economic value and resource burdens of a process (e.g. Seppala et al., 2005).