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The need for innovation management and decision guidance in sustainable process design

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ABSTRACT

The role of engineering science is to generate step changing technological solutions, leading to paradigm-shifts in innovation. But today, the path from discovery to innovation, and from innovation to industrial uptake has become more convoluted: the increased understanding of the wider impacts of technologies on environment and society has led to more complex and strict regulatory frameworks. New technological solutions must address a progressively larger number of simultaneous goals, among them is the contribution of technologies to sustainable development. To facilitate the success of translation of novel technologies into innovation and industrial adoption within Europe, the authors advocate an innovation management and a new decision-making approach, which promotes holistic understanding of economic, environmental and societal challenges that a new technology must respond to. The MEASURE approach was developed based on experiences in sustainability assessment and innovation management within previous collaborative projects, and the outcomes of two stakeholder workshops. It allows comparison of alternative solutions, understanding of their benefits and drawbacks, as well as the evaluation of the (remaining) distance to a defined target and, as a result, robust holistic decision-making for innovative sustainable process design. We propose an iterative stage-and-gate approach coupled with sustainability assessment and multi-criteria decision analysis. The paper exemplifies how development teams could set their own most informative criteria, the necessary gates and key targets. It is mainly intended to support technology-driven collaborative research projects between industry and academia within the European Horizon 2020 framework programme, as being an integral part of the Innovation Union Flagship Initiative.

1. Introduction

Globalization has changed the industrial landscape in many individual countries and regions (Ashford and Hall, 2011). Today, many European industries face rigorous competition and some are lacking competitiveness on the world scale (EC, 2010; Tello and Weerdmeester, 2013). The consequences for the region are: a relatively low growth, low pace of innovation, and many societal changes resulting from de-industrialisation. “Green” innovations, triggering decoupling of economic success from the need for non-renewable resources, and from environmental impacts, is seen as the key to drive economic growth, promote innovation, and maintain well-being within the European Union (Tello and Weerdmeester, 2013). We know that innovative economies respond much better to changes and see higher returns on investments (Stern, 2014). However, in practice, a serious “valley of death” between research and industrial uptake in Europe has been identified (EC, 2013). For this reason, the development of decision-support tools to facilitate the translation of basic and applied research in ‘green’ technologies into innovations and towards implementation, is a critically important element of the research landscape.

Bringing the experiences and learnings in eco-innovation from the past together with current overarching political strategies is a core aim of the European Horizon 2020 framework programme

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(H2020). Within the programme, significant amount of funding is directed to projects that respond to the strategic European agenda and priority areas towards a more sustainable future, for example, Key Enabling Technologies (KET) (EC, 2015), circular economy (EC, 2014b), energy and material resource efficiency (EC, 2011a, 2012), and competitive low carbon economy (EC, 2011c). A significant departure from the earlier framework programmes is that H2020 projects are set out by a number of Public Private Partnerships (PPPs), such as the European Institute for Innovation and Technology (EIT) and Joint Technology Initiatives (JTIs), instead of directly by the European Agencies advising to the Directorates General. Industrial innovation is the primary objective for the PPP projects. To demonstrate innovation outcomes most projects would have identified specific case studies that illustrate the translation of science into industrial reality at a pre-defined scale, or reaching pre-defined targets aligned with the core aims of the framework. One of the PPPs is the Sustainable Process Industry through Resource and Energy Efficiency (SPIRE), focusing on the development of KETs in European process industries (EC, 2011b; Ghinea, 2014; Tello and Weerdmeester, 2013). SPIRE includes eight sectors: chemicals, cement, ceramics, minerals, steel, non-ferrous metals, industrial water and process engineering.

Strong focus on innovation and on achieving specific outcomes within industrial setting is a significant change from the more traditional Research and Innovation Actions (RIA) in the European research projects that are aimed at developing the fundamental understanding, discovery of new materials, or developing completely new technology. In other words, to projects that would be classified as corresponding to Technology Readiness Levels (TRLs) 1–4, using the definition by NASA (Mankins, 1995). In order to foster innovation and pursuing a harmonised approach towards expected project outcomes, the SPIRE PPP has adopted its own definitions of TRLs (EC, 2011c; Ghinea, 2014). The major change is the need to focus research efforts and all activities within a project on achieving a main objective of delivering a demonstration case study (TRL level 7), which has to fulfil the pre-defined sustainability targets. That is why most SPIRE innovation projects are expected to start on a TRL level of 4–5, technology validation on laboratory scale or in a relevant technical environment, instead of the more curiosity-driven fundamental research, corresponding to TRLs 1–4, and meet sustainability goals set out in the project call.

How innovation management, instead of solely project management, could be efficiently implemented towards an emerging sustainable technological development, will be discussed and exemplified in this paper. The proposed methodology is based on recent advances in research on operational and innovation management, multi-criteria decision support, as well as on generalisation of heuristics learned through recent European projects by the authors. It should aid in successful translation of ideas into sustainable innovations by means of a stage-and-gate based innovation management (based on the stage-gate® concept proposed by Cooper and Kleinschmidt (Cooper and Kleinschmidt, 1990, 1991)), coupled with sustainability assessment and multi-criteria decision analysis (MCDA). In Section 2, a brief background of existing concepts, methods and actual discussions with regard to innovation management is given, before the idea of innovation management within publically funded projects is exemplified by means of two case studies. The proposed innovation management approach is detailed in Section 3.

2. Background

2.1. Concepts to implement eco-innovations

Over the last two decades, a fundamental paradigm shift in understanding and implementation of eco-innovations took place. López and Montalvo exemplified this paradigm shift on the case of the chemical industry (López and Montalvo, 2015). Whereas until recently, normative institutions and corporate environmental responsibility played the most important role in fostering eco-innovations, today the possibility of radical, breakthrough, eco-innovation is seen as the main driver for a new era of 'green' growth and prosperity. The future of "sustainable chemical manufacturing" is seen in technologies addressing climate change mitigation, use of renewable chemicals, development of functional nano-materials, and emergence of synthetic biology, which have been signposted with potential to contribute to an upsurge of manufacturing. Consequently, companies aiming for technology leadership in these areas associated themselves with the World Business Council for Sustainable Development (WBCSD) or sector-specific initiatives such as SusChem.

Ashford and Hall investigated the importance of innovation, particularly disrupting technological innovations, for both future competitiveness of industries and environmental protection, using a scientific methodology (Ashford and Hall, 2011). Others discuss the essential need for governmental policies in order to meet the sustainability challenge that society is demanding (Brandoni and Polonara, 2012; Marcelino-Sádaba et al., 2015). To give an example, Droste et al. illustrated the broad potential of diverse government interventions besides regulation, for example public procurement and investment, setting incentives and raising revenues, network and capacity building, and monitoring processes (Droste et al., 2016). Publicly funded projects between industry and academia can be a powerful instrument to merge creativity, expertise, regulation and capability of implementation. There is an ongoing discussion on the topic of sustainability in the context of project management (Silvius et al., 2013). Martens and Carvalho recently provided a thorough overview of the complex research framework for sustainability in industrial project management and project success (Martens and Carvalho, 2016). One can learn from sustainable innovation patterns in firms, described as non-linear and complex, which include several positive and negative feedback loops, self-organization actions, leading to different rates of changes up to rule-breaking, disrupting decisions (Iñigo and Albareda, 2016), adopting this learning to innovation management in publicly funded development projects. Nevertheless, transforming strategic sustainability objectives into specific actions for projects is seen as a complicated process, due to the multidimensional perspective of sustainability, combined with the current lack of (i) structured methods and (ii) data for the assessment (Marcelino-Sádaba et al., 2015). Among others, Marcelino-Sádaba and colleagues strongly recommend a better linkage between the two disciplines, sustainability and project management, the latter typically focusing on financial sustainment rather than sustainability as a whole, that traditionally have been tackled separately. This brief overview stresses the need for and the importance of informed decision-making, by coupling of process or product design and sustainability assessment in European collaborative development projects between industry and academia. First attempts have been already successfully implemented in the former European FP7th research programme, see for example (Kralisch et al., 2013b, 2013c).

2.2. The innovation funnel

Fundamental research at the cutting edge of science can lead to unexpected discoveries and is continuously facing new challenges. This is commonly represented as an innovation funnel. At an early stage of Research and Development (R&D) the aim is set, but the technical solutions that achieve that aim are yet unknown. There

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