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Development and deployment drivers of clean technology innovations

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ABSTRACT

Despite the existing challenges in the capital market, technological and market uncertainties, the current business environment may be fertile for innovative firms that could find affordable and scalable clean technology innovations. Navigating innovation management process for any clean technology project is a practical issue that requires attention of financial and non-financial factors affecting technology development and deployment. Such endeavor has precipitated many of the complex questions involved with clean technology industry. This article surveys literatures on resource-based view of the firm, operations management, innovation and technology management, and clean technology. The article identifies key drivers – operations, market and regulatory – of clean technology projects, and further demonstrates their interrelatedness within a comprehensive integrated conceptual framework of development and deployment. This integrated framework contributes to our understanding of innovation management process for clean technology firms, including supply and demand sides.

1. Introduction

Despite considerable challenges in the capital market, the clean technology, including clean energy (wind, solar, water, biomass, biofuels, hydrogen, geothermal, fuel cells), green transportation, green chemistry, information technology and energy efficient appliances, has been a growing interest for financing (Noci & Verganti, 1999). Amid the soaring energy consumption of the world economies, the need to overcome the challenges regarding the development and deployment of this industry has become increasingly crucial. The key to successful transition from a fossil-fuel economy to a sustainable economy depends directly on the progress in the clean technology field. Therefore, clean technology has been at the core of governments' economic recovery efforts to rebuild economies.

With increased attention and investment, much of the anticipated growth of clean technology across the globe has been counting on firms to figure out business strategies and models to mitigate the financial risks and produce technically feasible and economically viable results. According to Cleantech Group, the clean technology industry has attracted the most venture investments of any sector in recent years, surpassing software or biotechnology (Makower, Pernick, & Wilder, 2012). Indeed, the pursuit of sustainability is already reforming the way companies think about products, processes, technologies and business models (Nidumolu, Prahalad, & Rangaswami, 2009). In particular, clean technology regarded as new or modified processes, techniques, practices, systems and products plays key roles in achieving the goals of environmental technology management to avoid or reduce environmental harms (Beise & Rennings, 2005). In this article we focus on game changing sustainable technologies that would improve the input–output efficiency of systems through minimization of material use, waste, emissions from operations and energy use; substituting for less impact inputs and renewable energy sources; and adopting an environmental technology (Lewis, Gertsakis, Grant, Morelli, & Sweatman, 2001, chap. 3).

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However, this transition to clean technology is not prone to the vagaries of business lifecycle. The 2008 economic crisis with the relatively low cost of providing fossil fuels supports the notion that the clean technology industry was not immune to capital market frictions and susceptible to shocks in the credit markets and volatility. This is because of multiple reasons. First, clean technology investments involve high levels of technical and operational complexity which is hard to communicate with external investors, social communities and governments. The majority of clean technology firms rely on project financing from banks or other institutions to fund their capital outlays (Erzurumlu, Tanrisever, & Joglekar, 2011). Hence, informational asymmetries and their financial consequences are more likely to be severe in this market. Second, clean technology firms invest heavily in innovations with long cycles of development and uncertain returns. During these cycles the market and regulatory framework are prone to drastic changes, which could impact the course of technology development. Finally, clean technology firms require high levels of intangible assets (e.g., customer commitments and changes in behavior, market development) and very specialized tangible assets (e.g., R&D investments, infrastructural developments). Such assets usually have low liquidation value for effective use as collateral by creditors (Berger & Udell, 2002).

These reasons indicate that clean technology projects bear unique investment and growth opportunities as well as financial and non-financial constraints for technology development and deployment processes. Therefore, such innovative opportunities that determine the growth of the clean technology industry have to be accompanied with the innovation management process that generates economic feasibility of the clean technology project. Further, for effective innovation management an innovator could increase its financing chances by mitigating various supply and demand side risks. Therefore, the effort to refocus and consolidate the activities of the supply and demand side of a clean technology project has become necessary for firms to overcome development and deployment hurdles.

Accordingly, an innovative firm must understand the drivers of a clean technology project to fully assess development and deployment opportunities and overcome any shortcomings for resources over time. Such conceptualization is not only important in itself, but also because the comprehensive design is simply a practical issue for any project that requires immediate attention of financial and non-financial resources and has precipitated many of the complex questions involved with the technical feasibility and economic viability of clean technology investments (Erzurumlu et al., 2011). In particular, this article takes a holistic view of resources and processes throughout the multistage innovation and adoption of clean technologies to identify the drivers of clean technology development and deployment.

In general, the development and deployment of a technology is related to managing supply and demand sides which impede or accelerate the innovation and diffusion of a productive technology (Rothenberg & Zyglidopoulos, 2003). Clean technology innovations are not necessarily influenced the same way or by the same factors that motivate other types of innovations (Nameroff, Garant, & Albert, 2004). Firms must consider specific internal features which facilitate the firm's involvement and commitment; external factors stemming from social, institutional and market actors; and the characteristics of the environmental technologies (Del Rio Gonzalez, 2009). Thus, a precise perspective of all drivers is essential. There has been interest in the academic literature to identify the determinants of environmental innovations (Berkhout & Green, 2002; Corbett & Klassen, 2006), but no prior research has considered innovation management as a process of clean technology development and deployment with changing success drivers at each stage.

Our analysis identifies three major technology drivers–operations (supply side), marketing (demand side), and regulatory–for any clean technology change. In consideration of these drivers the firm should also take into account the technology lifecycle phases of development and deployment, and follow an integrated conceptual framework of these drivers. Relevant to the configuration of resources and processes in settings for clean technology projects, we ground our theory development within four related domains of literature: the resource-based view (RBV), operations management, innovation and technology management, and clean technology and energy. Synthesizing insights from multiple research streams we propose an integrated conceptual view to answer the following research questions: *What are the drivers of a clean technology innovation project? How should the firm address these drivers during each stage of technology development and deployment?* The technical and economic feasibility of a clean technology project could then be tackled based on where the firm resides on understanding and acting on these drivers. This article reviews background for three major technology drivers through the stages of technology development and commercialization process, proposes propositions for testing and provides an integrated conceptual framework.

The outline of the article is as follows. The next section identifies the operations, market and regulatory drivers for the clean technology industry. In Section 3 we then address the design of an integrated conceptual framework to incorporate a holistic view for decision making. We offer concluding observations and managerial implications in the final section.

2. Development and deployment of clean technology projects

Assessing the launch and growth of a new technology, the firm has to consider the following basic stages: basic R&D regarding technological details of the ideas, demonstration of testing new technologies and their economic viability, and deployment of new technologies at scale (Sagar & van der Zwaan, 2006). In particular, the aim for the firms should be to make the least possible investment to first prove itself (technological feasibility and economic viability) at the margin and then progress into the mainstream. Accordingly, we consider that a clean technology firm must manage operations in two major stages: invention and development of a new and clean product or process technology, and the adoption and use (deployment) of the clean technology over time (Jaffe, Newell, & Stavins, 2002). While the development stage seeks creativity with leadership, the deployment stage requires technology integration and marketing experience. In this paper we do not consider the sources of these innovative