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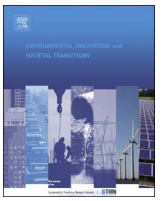

Original Research Paper

An intermediary approach to technological innovation systems (TIS)—The case of the cleantech sector in Finland

Jani Lukkarinen[a,*], Annukka Berg[b], Marja Salo[a], Pasi Tainio[a], Katriina Alhola[a], Riina Antikainen[a]

[a] Finnish Environment Institute, Mechelininkatu 34a, 00251 Helsinki, Finland
[b] Prime Minister's Office Finland, Finland

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ABSTRACT

The Technological Innovation System (TIS) framework has become a popular tool for the analysis of innovation dynamics, particularly on a national scale. There have been calls to utilise the framework at sub-national levels too, and to pay attention to location-specific features and interactions. This article contributes to the discussion by studying how the sub-national intermediary network of the Finnish Carbon-Neutral Municipalities (HINKU) complements and challenges the national cleantech innovation system in Finland. To achieve this, we propose an analytical framework that combines the TIS framework with intermediary functions. Our study shows that the TIS framework is a practical tool for analysing potential discontinuities and policy development possibilities regarding innovation systems across spatial scales. Empirically, the study reveals the ways in which certain technological innovation system functions, such as market formation and experimentation, are particularly important for local-scale cleantech deployment and should be analysed further.

1. Introduction

The deployment of cleaner solutions is widely seen as a necessary step in overcoming multiple challenges, including climate change, a deficiency of renewable and non-renewable resources and the persistent economic downturn (OECD, 2011; EEA, 2015). Cleantech refers to products, processes and solutions that harness renewable energy and material sources and lead to a significantly reduced environmental impact during their lifecycle, compared to their conventional counterparts (Stack et al., 2007; Makower, 2001). Significant cleantech innovations can lead to societal and economic transitions (Rennings, 2000). However, commercialisation is a crucial step in the actual deployment of innovations (Jalkala et al., 2014).

The relationship between policies and their role in the development of cleaner technologies, markets and economic growth has attracted continuous attention (Alkemade et al., 2011; Panapanaan et al., 2014; Boon and Bakker, 2016; Reichardt and Rogge, 2016). The Technological Innovation System (TIS) framework has become a popular tool for analysing innovation systems and policy development potential, particularly on a national scale. Innovation system refers to the flows of technology and information between people, enterprises and institutions, which is seen as the key to improving technology performance and the innovation process (OECD, 1997). The innovation system deploys a number of dynamic key processes, or functions, which directly influence the development, diffusion and use of new technology and, thus, the performance of the innovation system (Hekkert et al., 2007; Bergek

* Corresponding author.
E-mail addresses: jani.lukkarinen@ymparisto.fi (J. Lukkarinen), annukka.berg@vnk.fi (A. Berg), marja.salo@ymparisto.fi (M. Salo), pasi.tainio@ymparisto.fi (P. Tainio), katriina.alhola@ymparisto.fi (K. Alhola), riina.antikainen@ymparisto.fi (R. Antikainen).

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et al., 2008; Kivimaa and Virkamäki, 2014). TIS is a fruitful approach for studying innovation networks and their dynamics because it is rooted in sustainability transitions literature and complements the previous system approaches to innovation policy with a process focus. Furthermore, the TIS matrix offers a well-developed categorisation of processes that are relevant to the development of an innovation system and related to factors that public policies can potentially address (Kivimaa and Virkamäki, 2014). The TIS approach has also been specifically developed to inform policy development (Markard et al., 2015) and it has the ability to highlight pitfalls in the current policy framework.

In addition to national-level analyses, there have been calls to utilise the TIS framework to study sub-national innovation systems, and to develop the framework to be more open towards particular local contexts (Coenen et al., 2012; Raven et al., 2012; Hansen and Coenen, 2015; see also Markard et al., 2015). This article answers the call by applying the TIS approach to analyse the cleantech innovation system beyond just the national scale in Finland. To analyse place-specific dynamics, we turn to the intermediary niche functions identified in the literature (Kivimaa, 2014). First, we identify the strengths and weaknesses of Finland's national cleantech innovation system. Then we focus on the TIS functions performed by the sub-national intermediary network of Carbon Neutral Municipalities (HINKU), consisting of frontrunner municipalities in low-carbon solution deployment and social innovations. Finally we extend the framework to local level by studying intermediary functions in the case of a successful member of the network − the municipality of Ii.

We are interested in the dynamic relationship between national and sub-national systems. To carry out this task, we develop a framework that combines the TIS approach with intermediary functions. Our research questions are:

- What are the strengths and weaknesses of the national cleantech TIS in Finland?
- How does the sub-national intermediary network HINKU complement and challenge national cleantech innovation system and affect local cleantech development and deployment?
- How can we combine the popular TIS and intermediary frameworks to analyse policy development possibilities across spatial scales?

The rest of the article is structured in three sections. We begin by providing an overview of the TIS framework and proposing a way of combining it with intermediary functions. Second, we introduce the materials and methods of the study. Third, we analyse Finland's national innovation system, the role of the intermediary HINKU network in complementing and challenging the national TIS and a local case study of the municipality of Ii. We close the article with a discussion and relevant policy recommendations.

2. Material and methods

2.1. TIS framework and the roles of systemic intermediaries

Conceptually, a TIS is composed of the *actors, networks and institutions* contributing to the overall function of developing, diffusing and utilising new products and processes. Therefore, a TIS contains multiple components that influence the innovation process for technology – and not only those exclusively dedicated to the technology in question (Bergek et al., 2008). The TIS approach has been developed to analyse system performance and the factors affecting that performance (Hekkert et al., 2007).

Carlsson et al. (2002) recognise policy bodies and other public organisations as part of a well-functioning system. In particular in the field of sustainability transitions, *policies* occupy a central position in socio-technical transitions. As highlighted by Jacobsson and Bergek (2011), innovation system analysis is a tool to identify potential means of intervention at a systemic level. In the analysis of cleantech policies, the TIS approach has been applied to study policy mixes covering several sectors of policy making related to low-carbon passenger transport in Finland (Kivimaa and Virkamäki, 2014) and low-energy policies in Finland and the UK (Kivimaa and Kern, 2016), for example. We depart from using TIS to looking at the development of a system around a singular technology, and broaden it out to cleantech deployment affecting technological innovation systems of multiple technologies (cf. Kivimaa and Virkamäki, 2014).

In sustainability transition studies, the *national scale* with established actors and existing regulations is often seen as a 'natural' system boundary. However, there has been a call for more location- and space-sensitive approaches in sustainability and socio-technical transition studies (e.g. Coenen et al., 2012). Recent contributions applying TIS approach on different geographical scales include the case of photovoltaic (PV) adoption in Germany from the perspectives of regional differences (Dewald and Truffer, 2012) and at the geographical scale as the PV system matures (Dewald and Fromhold-Eisebith, 2015). There is also an emerging literature on the role of regional innovation systems in sustainability transitions (Mattes et al., 2015), but this has not been connected to the TIS framework. Another relevant example is provided by Späth and Rohracher (2012), who studied a regional energy initiative in Austria and the local–national interactions in energy transitions.

The role of intermediaries working between actors – policy-makers, entrepreneurs, funders, producers, users – in sustainability transitions is another line of inquiry that has gained momentum in recent years (Kivimaa 2014). The role of strategically located *systemic intermediaries* that have the capacity to align actors and communicate specified demands to effect systemic change is especially interesting (van Lente et al., 2003; Klerkx and Leeuwis, 2009). Furthermore, the work of intermediaries and specific intermediary functions in energy transitions have been conceptualised in relation to a *strategic niche management* (SNM) framework (Seyfang et al., 2014; Kivimaa, 2014). However, to our knowledge, combining an intermediary approach with a TIS framework has not previously been attempted.

The above mentioned studies serve as a starting point for our venture to analyse the differences and similarities between national