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Socio-technical barriers to the use of energy-efficient timber drying technology in New Zealand

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HIGHLIGHTS

- Firms processing timber in New Zealand use two main drying technologies.
- Relatively inefficient vented dryers dominate over energy-efficient heat pumps.
- Operating costs are similar but the socio-technical regime supports vented dryers.
- Stasis is created by fixed energy cultures both within firms and across the sector.
- Stasis hampers technical development in heat pump drying and business innovation.

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ABSTRACT

This study of industrial energy behaviours identifies barriers to the use of energy-efficient drying technology in the New Zealand timber industry, and explores these barriers through the “energy cultures” lens. Vented kiln dryers were preferred by larger firms and heat pump kiln dryers were used by smaller firms. Although few firms could specify all their costs, we found no significant differences in the average operating costs, drying costs or commercial success of the larger and smaller firms. We found that socio-technical barriers create “energy cultures” at the level of both the firm and the sector, supporting the dominance of vented kiln dryers. The prevailing technologies, practices and norms at the sector level strongly support vented kilns, the status quo being embedded in the socio-technical context, hindering technological learning, improved energy efficiency and innovation. Influential stakeholders in the industry were thus part of, and locked into, the industry-wide energy culture, and were not in a position to effect change. We conclude that actors external to the prevailing industry energy culture need to leverage change in the industry norms, practices and/or technologies in order to reap the advantages of energy-efficient drying technology, assist its continued evolution and avoid the risks of path-dependency.

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1. Introduction

It is well accepted that improved consumer energy efficiency is an important and cost-effective option for reducing global greenhouse gas emissions (Laitner, 2013). Referring to earlier IEA studies, Stern (2007: xiii) noted that energy efficiency has “the potential to be the biggest single source of emissions savings in the energy sector” by 2050, a view further endorsed by the International Energy Agency, (2012). However the diffusion of energy efficient technologies is relatively slow (York et al., 1978; Shama, 1983) because energy technologies tend to be long-lived, capital intensive, interlocked with other technology networks, and have high learning needs. The possibility of accelerating the uptake of energy efficient technologies is widely seen as a challenge in economics, innovation studies and energy systems (Chai and Yeo, 2012; Geels and Schot, 2007; Grübler et al., 1999; Klapowitz et al., 2012; Lutzenhiser, 1993; Stephenson et al., 2010; Thollander and Ottosson, 2007).

Among the theoretical models for energy consumption decisions is the Energy Cultures framework proposed by Stephenson et al. (2010) to integrate multi-disciplinary perspectives on the drivers of energy decision-making, drawing in part from socio-technical systems literature (Rotman et al., 2001; Geels, 2004; Smith et al., 2005). Applying the framework to the energy decisions of industrial firms, it distinguishes the external drivers of a firm's decisions from the internal, over which the firm has agency. External drivers include commercial pressures, technology

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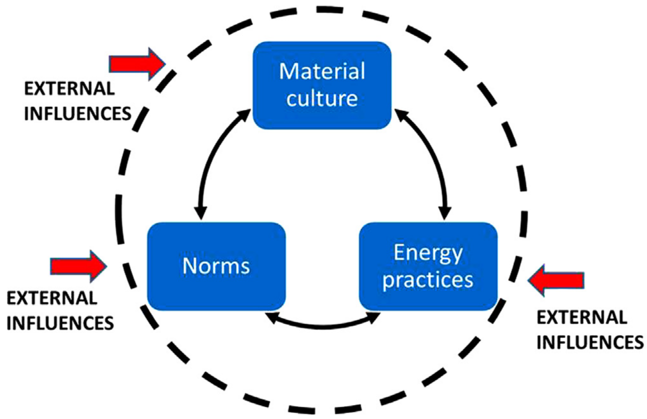

Fig. 1. The Energy Cultures framework (adapted from Stephenson et al. (2010) showing energy culture as the self-reinforcing internal interactions between material culture (energy-related technologies and physical infrastructure), energy practices and norms. These in turn are affected by external influences that may either act to reinforce the culture or to change it.

networks and supply firm interventions. Internal drivers are grouped into energy-using activities ("practices"), physical technologies and infrastructure ("material culture"), and mental models of what is normal or appropriate ("norms"). Because of feedbacks, these multi-level influences have the potential to create a durable culture of habitual energy decision-making (Fig. 1), representing a socio-technical barrier for a firm to change its energy decisions. For effective policy responses, it is important to understand the interactive nature of socio-technical barriers affecting the deployment of energy efficient technologies (Geels and Schot, 2007), so that they can be addressed effectively.

In this paper we use the Energy Cultures framework to identify and understand socio-technical barriers influencing the energy decisions of small and medium-sized timber processing firms in New Zealand. Because timber drying, on average, requires more than 95% of the energy consumed by these firms (EECA, 2005), the paper focusses on the drying operation.

In New Zealand most timber is dried using conventional vented dryers, but about 3% is dried using heat pump dryers, which are more energy efficient and have a number of environmental and commercial advantages. One might reasonably expect heat pump drying technology to be used more than this and it is unclear why many firms in this industry reject heat pump technology so comprehensively. The purpose of this paper is to identify the drivers and barriers for the timber drying decisions of these firms.

In Sections 2 and 3 we discuss the timber processing industry in New Zealand and describe our research methods. The results of interviews with twenty small and medium-sized timber firms in 2009 are presented in Section 4. In Section 5 we discuss the results and their implications by considering four questions, formulated iteratively as our understanding of the issues evolved. They are: What is the main success factor in timber processing? Why are certain timber dryers preferred? Are there socio-technical barriers to alternative dryer technologies? Is there a future for energy-efficient timber drying? In our conclusion, Section 6, we consider what we can learn from this study to inform low-emission, energy-efficient, technology deployment more generally.

2. Industry background

New Zealand produced 3.5 M m^3 of sawn softwood from plantation sources in 2009 (MPI, 2012). The price paid for logs at that time was approximately $NZ120/tonne (MPI, 2013) and radiata pine dominated both domestic and export timber sales. Based on EECA, (2005) and MED, (2012) data the sawmilling industry in New Zealand uses approximately 2% of all domestic consumer energy and 4% of electricity production. Drying is important because it reduces biological attack, distortion and crack development in sawn timber (Perré and Keey, 2006) and reduces transport costs. The quality of the drying process determines the market value of the sawn-wood (Alexiadis, 2003).

Conventional vented kilns operate at temperatures of 70–120 °C and the energy used is typically 3.2 GJ/m^3 (EECA, 2005). Of this energy, 7% is supplied as electricity, the balance being in the form of heat produced by burning coal, natural gas or sawmill residues. Heat pump kilns are different; they use a type of air-conditioner to dry the timber (Carrington, 2007), and consume only electricity, typically 0.5 GJ/m^3 (Van der Pal et al., 2005). Based on these data, heat pump dryers are 84% more energy efficient than vented kilns. The reason heat pump dryers are so efficient is that heat is recycled within the dryer. On the other hand, they typically use twice the electrical energy per cubic-metre of sawn-wood as vented kilns and operate at lower temperatures, 50–60 °C, so drying times are longer.

Atmospheric emissions represent another point of difference between the two technologies. Vented kilns produce combustion emissions, such as particulates and carbon dioxide, generating 345 kg CO_{2-e} per cubic-metre of sawn timber, based on the emission factors for wood combustion and electricity in 2009 (MBIE, 2012). If all of New Zealand′s sawn softwood were dried with such kilns, the atmospheric emissions would be 1.1 Mtonnes CO_{2-e} per annum, 3.9% of national combustion emissions (MBIE, 2012). By comparison, the emissions per cubic-metre of product dried with heat pump kilns are 25 kg CO_{2-e}, a reduction of 92%. This comparison does not take account of the fact sawmill residues, used by many firms, are a carbon-neutral fuel. Approximately 75% of New Zealand's electricity is generated from renewable resources, so the emissions benefit is larger than in countries where the fraction of electricity generated by fossil-fuels is greater.

Particulate emissions are regulated in New Zealand, but volatile organic compounds (VOCs), mostly monoterpines (McDonald et al., 2002), are not. Based on the rates reported by Pang et al. (2006), national emissions of VOCs by vented timber drying kilns are approximately 300 t per annum. By comparison, in an unvented heat pump kiln the release of VOCs is substantially reduced or eliminated. Simpson (2004) reported no terpines in the condensate of an unvented heat pump kiln drying radiata pine.

Another difference between the two technologies is the effect of the higher temperatures used in vented kilns on product quality. Drying at higher temperatures reduces the value of high-quality grades of radiata pine due to colour development (McCurdy et al., 2004), kiln-brown-stain (Kreber and Haslett, 1997) and internal checking (Haslett and Dakin, 2001). These effects are reduced by drying at the lower temperatures presently used in heat pump dryers (Perré and Keey, 2006).

In spite of these features, heat pump kilns have limited penetration in the New Zealand market, producing some 2.8% of the volume of dried lumber in 2001 (Bannister et al., 2002), which is similar to other countries with significant softwood processing industries. Alexiadis (2003) found that 8.8% of timber kilns in Canada were of the heat pump type. A report by Cooper (2003) on energy efficiency in wood drying kilns in Europe indicated that heat pump timber kilns were not viewed there as a mainstream technology. In a review of wood drying principles and practices internationally, (Perré and Keey, 2006) include heat pump dryers among the "less-common drying methods".

3. Research methods

The authors of the paper have disciplinary backgrounds in sociology, engineering/physics, consumer psychology and human

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