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A new regime and then what? Cracks and tensions in the socio-technical regime of the Swedish heat energy system

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ABSTRACT

Since the 70s, Sweden has gradually replaced oil with renewables to provide energy for heating, and today the country uses the highest total amount of renewable energy for heating of all EU Member States. However, there are signs of new tensions in the heat-energy system, and of lock-in of less sustainable practices. Using the multi-level perspective (MLP), this paper assesses to what degree the sociotechnical regime in Sweden's heat-energy system is stable and locked-in, and whether there are emerging tensions. We identify three key characteristics of the regime – interconnectedness, complementarity and saturation – that together risk creating tensions and lock-in of less sustainable practices. We conclude that the heat regime is facing an unstable future, with several challenges of growing importance.

1. Introduction

Sweden has successfully initiated a transition to a low-carbon energy system, reducing domestic greenhouse gas emissions by 24% from 1990 to 2014 and by more than 40% since the mid-1970s [1]. This paper focuses on energy for heat, where the share of fossil fuels is now below 5%. It is well known that Sweden has achieved this decarbonisation by removing oil and other fossil fuels for heating in both detached homes [2] and multi-dwellings [3] over the past 50 years. They were replaced by two interconnected supply-side heat systems that provide up to 75% of the energy demand for heating in buildings: district heating (DH) and electricity through resistive heating and heat pumps (HP), both of which are almost completely decarbonised. Oil, which dominated the heat system from its introduction in 1940s until 1970s, had a less than 3% share in 2012 [4]. Since 1990, energy use for electric heating has decreased by 25%, largely due to HP efficiency improvements [5]. Today, DH delivers more than 50% of the generated heat in the building stock, compared with about 6% across the EU [4,6]. Another 20–25% of the heat is from electricity, much of it through HP. Overall, Sweden has the highest share of renewable energy in the heat domain in the EU [7].

Several studies have examined the role of individual technologies in this transition, with DH. For example, Ericsson and Werner [3] and Di Lucia and Ericsson [8] have focused on the processes behind fuel switching from fossil to renewables. However, there are few system-level, interdisciplinary analyses of how this set of technologies came to dominate the Swedish residential heat system. There are also few studies of the challenges faced by the new regime [9,10]. This paper draws on lessons from past successful socio-technical transitions in Sweden to examine the regime dynamics of the heat energy system and analyse the potential for technological lock-in. The experience of Sweden, a forerunner in such low-carbon systems, could provide useful insights for low-carbon transitions in other countries.

Our analysis follows a socio-technical perspective [11,12]. We apply a case study approach [13], following the multi-level perspective (MLP) [11,14,15] to organise and analyse the data. The MLP framework, described in Section 2.1, offers a useful tool to explore the dynamics between incumbent regimes – the technological configurations and rules and practices that dominate the socio-technical system – and niches, the spaces where novelty grows [11,12]. Through qualitative analysis we recognise levels of social structuration, in which niches at the lower level challenge incumbent regimes at a higher level. The top level is the landscape – the slowly developing set of exogenous variables and processes that influence regime-niche dynamics [11,16]. MLP contributes interdisciplinary analysis to otherwise dominant techno-economic perspectives on energy transitions [17,18] and has been widely applied in studies of low-carbon transitions in energy and transport [19,20], including the low-carbon transition in DH in Sweden [8]. It has also been used in case studies of grid system development [21], sustainable mobility [22] and the energy industry

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[23,24], contributing to a broadening of analytical approaches [25,21,22].

While the Swedish heat system has undergone a transition and established better performance in terms of CO_2 emissions, it also involves less sustainable practices, such as waste incineration [26]. Thus, analysis of the Swedish heat system offers insights into successful low-carbon transitions as well as into the tensions that can arise in the transition to a new stable configuration [27]. This paper aims to contribute to the growing understanding of the longer-term stability and adaptation of new regimes in socio-technical transitions.

Our analysis starts by assessing the regime change processes that underpin Sweden's transition to a low-carbon heat energy system. Second, we investigate what happens after new regimes with improved environmental performance are established. Finally we ask what determines whether a new regime becomes incumbent and locks in new problems, or it continues to adapt, reinvent itself and improve its performance.

We found that the Swedish heat regime faces strong support from both policy and civil society. The heat regime is characterised by interconnectedness, complementarity and saturation. Through interconnectedness the regime has been able to usurp supply-oriented niches such as industrial waste heat, and complementarity between DH and HP has only strengthened the regime. However, recently, the market for the different technologies has shown signs of saturation and there are now increasing tensions between DH and HP.

Section 2 sets out our theoretical and methodological approach and explains how our analysis contributes to understanding of socio-technical regimes. Section 3 explains key historical factors that have shaped the Swedish heat energy domain. Section 4 presents empirical analysis of the composition of the historical and current regimes, as well as the niche developments that led to regime changes. Section 5 focuses on the most important challenges and adaptation needs in the regime today. Section 6 provides a brief summary and concluding thoughts.

2. Theory and method

2.1. The multi-level perspective

The MLP framework recognises three interconnected levels: the socio-technical regime – a semi-coherent set of rules and institutions that shapes the actions, interpretations and identities of social actors at the meso-level; niche innovations – radical novelties that deviate on one or more dimensions from existing regimes at the micro-level; and the socio-technical landscape – an exogenous macro-level environment beyond the direct influence of niche and regime actors [11]. The socio-technical regime forms the 'deep structure' that shapes the perceptions and actions of the incumbent actor groups who reproduce or change elements of socio-technical systems [28,30]. The MLP thus draws heavily on neo-institutional concepts of formal and informal institutions, with the latter containing cognitive and normative rules [31–34]. The links to institutional theory have only recently been recognised and discussed explicitly [35,28], however, and there is a lack of studies drawing explicitly on institutional theory [35].

In MLP, the term system refers to more tangible 'measurable' elements, such as artifacts, market shares, infrastructure, regulations, consumption patterns and public opinion, while the term regime is concerned in particular with underlying rules and institutions [30]. The strength of MLP has been to provide a heuristic framework for analysing how new technologies and new actors create societal transitions through innovation. As noted above, it has been used successfully in many case studies of socio-technical traditions over the past decade [19,20,22–24].

However, scholars applying the MLP framework to sustainability transitions tend to focus on 'green' niche-innovations and the role of new entrants [12]. This excludes important aspects of institutional change, such as the role of existing regimes and incumbent actors, and how change can be driven from within. In that context, the objective of transition management is to steer bottom-up niche-to-regime processes of transformation towards a pre-defined goal or 'vision' [36]. While these studies consider the stability of existing regimes, they often conceptualise it in terms of lock-in, path dependence and inertia [26,29], with less attention to the mechanisms behind this inertia. Explanations such as vested interests, organisational capital, sunk costs, economies of scale, increasing returns with refinement of production lines and skills, stable and favourable regulations, cognitive routines, social norms and behavioural patterns do arise in the literature. Still, regimes are often conceptualised as monolithic and homogenous [30,37,28] – as barriers to be overcome by creating protected spaces where green niches can grow [38].

Socio-technical regimes are deeply institutionalised [28], in a manner that reflects socio-technical patterns, but we know that institutions do change, albeit slowly [31–33,39]. MLP theory itself includes an understanding that transitions can be induced in different ways [14]: through a build-up of niche momentum, through shocks or changes in the landscape that put pressure on the regime, or through a combination of the two. This means there are different transition pathways, in which regime stability and change is an important factor [14]. Yet since the introduction of MLP theory, there has been much less attention on existing regimes and incumbent actors [40,28]. This has recently prompted studies of the need to destabilise and the processes by which this can occur [23,24], as well as studies of regime adjustments [41]. Empirical cases with explicit focus on regime change are slowly emerging [20], but the actual strength and change process of regimes needs further empirical analysis [30]. That is a key objective of this paper.

In particular, we seek to understand how the low-carbon transition in Sweden's heat energy system has established a new regime, as well as the on-going dynamics of that regime. We shift the focus to less structured processes and to how the regime is contested. From that perspective, the purpose of transition strategies is less to identify and implement consensual transition pathways, but rather to understand and engage with the emergent and contentious character of such change processes.

Regimes imply rules, technologies and actor-networks as the main components that can enforce stability or, when they change, create instability [42]. Building on this, we explore how three elements of regimes – i) technology and infrastructure, ii) intangible components, such as actor configurations, and iii) formal and informal institutions — explain how DH and HP became the central elements of the current heat regime. We will explore which components led to the regime change and which are causing new cracks and tensions. Like recent work by Geels and colleagues [19], this approach focuses on critically exploring technological development alongside policy-making and the norms, cognitive elements and routines that result in stable or dynamic regime actor configurations.

2.2. Three analytical dimensions of regime change

Technologies that provide improved or new services have been shown to play a key role in driving a transition, even if they are relatively expensive in the early stages [35]. It is clear that technological development is critical to regime destabilisation [24]. However, what is less studied is what happens after the transition. Our analysis considers how tensions and inconsistencies at the regime level – for example, between two energy-supply sources, or between supply and demand – affect how actors engage and intervene in conflicts and make sense of the situation [43,44].

Second, looking at actor configurations, we are interested in agents and structures and their mutually constitutive nature [45]. We need to know which are the important actor groups and what interests they represent, as well as their relationship to governance. The precise