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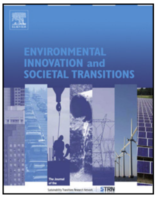

An agent-based model of transitions in consumer lighting: Policy impacts from the E.U. phase-out of incandescents

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A B S T R A C T

To understand the consequences of the E.U. ban on incandescent lamps, an agent-based model is developed in which consumer behaviour regarding purchase of lamps is simulated. Consumers are modelled as having heterogeneous and dynamic preferences on lamps. Development of preferences depends on memory and perceptions, as well as interaction in a social network structure. Lighting technology is modelled to cover many different lamps and technologies. The results indicate that the ban on bulbs will be effective in realising an energy efficient sector. Although the ban on bulbs causes a spike in consumers' purchases, the consequent benefits of energy saving outweigh the additional costs of purchasing these lamps. Introducing a tax on incandescent lamps would also be effective given a sufficiently high tax level and could be income-neutral with respect to purchasing lamps. A possible penetration of halogen lamps may hamper the transition to lower electricity consumption.

1. Introduction

Lighting is essential for modern living – it enables mankind to do many things that would otherwise be impossible. For example, lighting is essential for education, which is a first requirement for economic development. Whereas humanity has used artificial lighting for millennia, the last two centuries have seen dramatic increases in the use of lighting. From medieval candles to today's highly efficient gas

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discharge and solid state lamps, the lighting technology has progressed greatly, contributing to a large decline in cost of lighting service (Fouquet and Pearson, 2006).

Electric lighting really took off after 1879, when Thomas Edison demonstrated his durable, well-performing incandescent light bulb, by using it to light his Menlo Park laboratory complex (NPS, 2007). During the last decades of the 19th century, electric power stations were erected in major cities around the world, supplying current for up to a thousand of incandescent glow-lamps per electric station (Forbes, 1889), marking the beginning of the electric power infrastructure.

Edison's first carbon filament glow bulb had a lifetime of 45 h and an efficiency of 2 lm/W.[1] Many gradual improvements in electric lighting technologies (Gendre, 2003) increased the lifetime of the bulbs and the electric efficiency. By 1912, the glow bulb's efficiency had improved to reach a light output of 12 lm/W of electricity. Technological progress in incandescent bulbs stopped at that point. Presently, almost 100 years later, the incandescent lamps are hardly more efficient: even now, over 98% of the electricity used is converted into heat and not into light.

Today, consumer lighting contributes significantly to the ecological footprint of households and it is an important sector for energy saving.[2] More energy efficient alternatives have been developed, for example the compact fluorescent lamp (CFL, Azevedo et al., 2009). The CFL was first introduced by Philips in 1980, and offered four times energy savings and a much longer lifetime, with some disadvantages (size, weight). Subsequently, the CFL was much improved in the decades afterwards, and was known as the 'saving lamp'. The CFL enables a dramatic increase in the energy-efficiency of lighting while, partly being a screw-in/plug-in replacement, it retains an amount of compatibility with existing luminaires. CFLs offer clear benefits for many applications, and many governments tried to stimulate its use (see e.g., Mills, 1993; Martinot and Borg, 1998), but these stimulus programmes have only seen limited successes, and presently, CFL saving bulbs are present only in 55% of European households (Bertoldi and Atanasiu, 2007).

Another exciting development is solid-state lighting: the light-emitting diode (LED). General Electric introduced the first commercial (red) LED's in 1962 (Azevedo et al., 2009). Since then, the developments in LED technology have continued, and these days, LED lamps are a very promising alternative. In the laboratory, LED designs achieve unparalleled electric efficiencies compared with other light sources (Dupuis and Krames, 2008). Proponents consider the LED as the ultimate lamp of the future, because it is very suitable to a wide range of applications, and because it will continue to achieve significant gains in electric efficiency (Curtis, 2005; Department of Energy, 2009; Holonyak, 2005; Azevedo et al., 2009).

Consumers have adopted CFL and LED technology only partially because of a number of obstacles (Menanteau and Lefebvre, 2000). CFL and modern LED saving lamps are characterized by high up-front cost for consumers and poor light quality, which serve as a barrier for adoption. Consumers implicitly use high discount rates when purchasing energy efficient durable goods (Hausman, 1979; Kooreman, 1996). Halogen lamps proved more attractive because they fitted in popular designs and do not have the disadvantages that CFLs have.

In consumer lighting, changes are forthcoming. The European Union's phase-out of incandescent lighting is a clear strategy that will change the sector, it involves regulation designed to remove from stores the cheapest forms of inefficient household lighting (CEC, 2009). Although implied, it is uncertain whether the lighting sector will become efficient overnight; consumers may switch to forms of inefficient lighting that are exempt from the phase-out; or consumers' behaviour will change. As the phase-out has only recently been initiated, most of the effects induced by the phase-out are yet to occur. That implies that it is useful to explore what those effects may be.

Exploring such consequences is not straightforward, because the behaviour of consumer markets is complex (Gilbert et al., 2007; Jager, 2000). The myriad of decisions and interactions in the system determine the short and long run impact and the effectiveness of policies, i.e. decisions made by

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[1] Light output is measured in lumen (lm). An ordinary incandescent 75 W bulb (which is now banned in the EU) emits more or less 900 lumen at 12 lm/W. The theoretical maximum is 683 lm/W, which makes it <2% efficient (Azevedo et al., 2009).

[2] For the Netherlands alone, the yearly electricity usage in consumer lighting equals 3.8 TWh_e, comparable with the output of one large coal power plant (typically 800 MW_e, see, Afman, 2010).