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# Public acceptance of environmentally friendly heating in Beijing: A case of a low temperature air source heat pump

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ABSTRACT

China has long suffered from severe pollution due to coal consumption in rural areas. One possible solution is the promotion of a new electric heating system, low temperature air source heat pump (LTHP) technology. This paper explores the possibility that the public will accept LTHPs for electric heating. We assess people's willingness to adopt (WTA) as well as willingness to pay (WTP) for LTHP technology and sociodemographic and perception information by conducting field surveys in rural Beijing and empirically characterize the determinants of public acceptance. The analysis reveals that income, science literacy and local environmental concern positively affect WTA and WTP, whereas global environmental concern does not. Contrary to our initial expectation, people in mountainous areas express the highest WTA and WTP, followed by those in hilly and plains areas. These findings suggest that efforts to promote this technology could begin in mountainous areas and move to hilly and then to plains areas, thereby advancing public education on local environmental concerns and science literacy. The adoption of such a plan has the potential to promote electric heating systems in the lowest-cost manner and ensures a cleaner environment through the shift from coal to electricity in rural Beijing.

## 1. Introduction

China has suffered from severe smog and haze pollution since 2012, and the high concentration of $PM_{2.5}$ has attracted considerable attention in China (Li and Liu, 2014; Wu et al., 2016).[1] Coal consumption is responsible for 22.4% of the $PM_{2.5}$ concentration in Beijing (Beijing Municipal Environmental Protection Bureau, 2014). Wu et al. (2016) find that coal consumption in rural Beijing has reached 4 million tons of coal equivalent (TCE) per year, of which 92% is used for space heating, with considerable pollution being generated from residential sectors due to incomplete coal combustion. To combat this problem, a switch in household energy sources from coal to electricity is advocated in rural Beijing (General Office of Beijing Municipal People's Government, 2014), and the government plans to broadly promote and subsidize electric heating using LTHP technology, which has been scientifically demonstrated to be effective in many aspects of rural life (General Office of Beijing Municipal People's Government, 2014; Chai et al., 2016).[2]

Beijing has promoted the switch of household energy source from coal to electricity in the core city area since 2001 and expanded this promotion to rural areas in 2013 (General Office of Beijing Municipal People's Government, 2013, 2014). A peak-valley time price policy was also introduced to subsidize the electricity price in rural households in 2015.[3] In 2016, it was announced that by 2020, the plains areas will entirely use cleaner energy for heating instead of coal (General Office of Beijing Municipal People's Government, 2016). Consequently, clean energy technologies (i.e., electricity and natural gas) have been widely promoted in plains areas. As a new technology, LTHP technology has

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[1] PM (particulate matter) is the sum of all solid and liquid particles suspended in the air. Particles 2.5 micrometers and smaller in diameter, denoted $PM_{2.5}$, pose the greatest health risks.

[2] LTHP technology is an environmentally friendly technology comprising an air-to-air source heat pump. The remarkable advantage of this technology is its good performance in cold climates with relatively lower investment and running cost, comfort, ease of use and no pollution emission. The steady-state coefficient of performance (COP) will not be lower than 2.0 on average throughout a winter season when the temperature is above or equal to − 20 °C. More detailed information is provided in the appendix.

[3] The details of the peak-valley time price policy are provided in the appendix.

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**Nomenclature**

| | |
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| CV | Contingent valuation |
| HEV | Hybrid electric vehicle |
| LTHP | Low temperature air source heat pump |
| PM | Particulate matter |
| RMB | Renminbi, Chinese currency |
| TCE | Tons of Coal Equivalent |
| WTA | Willingness to adopt |
| WTP | Willingness to pay |

been mostly promoted in demo projects without fixed subsidies of the adoption cost.

Many governmental policies intended to promote certain technologies among the public have been unsuccessful and led to significant social costs (Hallsworth et al., 2011). Thus, it is argued that policies used to promote technologies should be designed in advance and, crucially, on the basis of scientific evidence regarding public acceptance and needs (Sutcliffe and Court, 2005; Hallsworth et al., 2011). Moreover, there has been an important policy debate over how to promote LTHP technology in rural areas of China to ensure a cleaner environment (Lu, 2016). Many scholars suggest that LTHP technology should be promoted on a large scale based on its technological advantages, affordable investment and environmental friendliness (Jiang et al., 2016; Chai et al., 2016). In addition, the promotion of LTHP technology should consider topographical differences and prioritize colder areas (Ministry of environmental protection of the people's republic of China, 2016). Another concern is the financial burden associated with promoting clean energy and whether the mode of promotion used in Beijing is applicable in other parts of China (Cui, 2017). Thus, a sustainable promotion policy for LTHPs should be designed based on public acceptance of and satisfaction with the technology before wider promotion (Lu, 2016). Given this state of affairs, this paper addresses public acceptance of LTHP technology.

Several papers have studied the factors that influence the selection of sustainable or environmentally friendly residential heating systems in developed countries (see, e.g., Mahapatra and Gustavsson, 2008; Braun, 2010; Sopha et al., 2010; Lillemo et al., 2013; Karytsas and Theodoropoulou, 2014; Michelsen and Madlener, 2012, 2013, 2016). For instance, Sopha et al. (2010) compare the choice among electric heating systems, heat pumps and wood pellet stoves, arguing that sociodemographic factors, interaction among households, the perceived importance of heating system attributes and the decision strategy influence Norwegian homeowners' decisions. Lillemo et al. (2013) find that household and demographic factors, environmental attitudes and people's motives affect households' investment in heating and the choice among four types of heating equipment in Norway. Similarly, Karytsas and Theodoropoulou (2014) show that age, income, education and the presence of a person in a household that has an occupation or interest in the environment, technology and engineering or an awareness of renewable energy resources and alternative technologies affect people's willingness to adopt ground source heat pumps in Greece.

These studies address the adoption or selection among several sustainable heating systems in developed countries, where these sustainable heating systems are available and traded on the market. By contrast, few studies have focused on the determinants of public acceptance of environmentally friendly electric heating systems when the heating system in question is not traded on the market and will instead be promoted through government policies. Moreover, the public acceptance of environmentally friendly technologies has not yet been analyzed in the context of emerging and developing economies, where air pollution is more serious than in developed countries and modes of thinking are likely different (Gupta et al., 2011). Among developing countries, China suffers from particularly heavy air pollution and, as a primary contributor to haze and smog pollution, has attracted considerable attention from the media and other countries such as South Korea and Japan (Sun et al., 2016a). LTHP technology has been scientifically demonstrated to be effective in coping with air pollution in rural China. This paper empirically characterizes the determinants of public acceptance to evaluate the potential for public acceptance and contributes to promotion policies for LTHP technology.

To this end, we collect data through face-to-face surveys in rural Beijing regarding people's willingness to adopt (WTA) and willingness to pay (WTP) for LTHP technology to measure public acceptance, socioeconomic characteristics, such as income and education, and perception variables such as science literacy and environmental concerns. The LTHP is a private good of environmentally friendly electric heating technology. Given the technological advantages of LTHPs shown in the appendix, we ask respondents whether they are willing to adopt LTHP technology and how much they are willing to pay for one LTHP unit. We employ WTA and WTP in our analysis because the end users' WTA and WTP represent the market capacity, size or potential for LTHPs, thus providing an important reference point for policy makers to design appropriate promotion strategies and subsidy schemes for LTHP. Only the successful promotion of LTHPs can improve environmental sustainability. In other words, identifying the determinants of WTA and WTP will facilitate the promotion of LTHP technology to reduce air pollution in Beijing.

In addition to socioeconomic factors, our analysis focuses on the perception variables of environmental concerns, science literacy and spatial differences. Environmental concern is a fundamental determinant of people's WTP for environmentally friendly technologies (see e.g., Erdem et al., 2010; Ward et al., 2011; Daziano and Bolduc, 2013; Michelsen and Madlener, 2016). Based on these studies, we examine the impact of environmental concern on public acceptance of LTHP technology by adopting two levels of environmental concern (global and local levels). In addition, few studies have analyzed the relationship between science literacy and public attitudes toward science and technology. There is a debate on whether this relationship is positive or insignificant, and thus it is particularly valuable to further understand the role of science literacy in public acceptance of emerging technologies (Lee et al., 2005; Snow and Dibner, 2016). Another focus of our analysis is on spatial differences in public acceptance of space heating systems (see, e.g., Braun, 2010; Michelsen and Madlener, 2012, 2016). We seek to clarify area-specific effects on public acceptance of LTHP technology because the question of where to start the LTHP promotion project (in plains, hilly or mountainous areas) is an important point in the policy debate.

## 2. Literature review

In the field of household choices on space heating systems, revealed preferences (i.e., households that have adopted the technologies) or real adoption data are widely employed in past studies (Michelsen and Madlener, 2013; Ruokamo, 2016). Some studies mainly examine the influence of household-specific characteristics on people's choices (see, e.g., Dubin and McFadden, 1984; Vaage, 2000; Braun, 2010). For example, Braun (2010) analyzes the determinants of household choices among seven heating technologies and proves the importance of building types and regional differences in household heating choices in Germany. Other studies focus on the role of behavioral elements (i.e., system attributes and advantages, environmental consideration) in household heating choices (see, e.g., Mahapatra and Gustavsson, 2008; Nyrud et al., 2008; Sopha et al., 2010; Lillemo et al., 2013; Karytsas and Theodoropoulou, 2014; Michelsen and Madlener, 2012, 2013, 2016).

Nyrud et al. (2008) investigate adopter attitudes toward a new wood stove in Norway and find that economic benefits, comfort of use, heating and environmental performance mainly motivate them to continue using it. Michelsen and Madlener (2012, 2013, 2016) document the drivers or barriers of household motivation to adopt