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Sustainability effects of household-scale biogas in rural China

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HIGHLIGHTS

- ▸ Household biogas alleviated all sustainability issues targeted by policy.
- ▸ Biogas users consume less biomass fuels, much less LPG, but similar amounts of coal.
- ▸ Strongest sustainability effects are reduced workload and forest degradation.
- ▸ Household budget effects are slight as commercial cooking fuel use is limited.
- ▸ Low quality fuel use remains abundant and further policy efforts are needed

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ABSTRACT

Households in rural China rely heavily on low quality fuels which results in reduced quality of life and environmental degradation. This study assesses the comparative contribution of household scale biogas installations to the broad set of sustainability objectives in the Chinese biogas policy framework, which targets household budget, fuel collection workload, forest degradation, indoor air quality and health, renewable energy supply, and climate change. A household survey was used to determine how biogas affected consumption levels of crop residues, fuel wood, coal, LPG, and electricity. Biogas users were found to reduce consumption of biomass fuels but not coal. Although LPG is not a highly commonly used fuel in rural China, biogas users nearly cease to use it altogether. A big reduction in fuel wood consumption results in strongly reduced workload and forest degradation. Although household scale biogas has alleviated all sustainability issues targeted by Chinese policies, low quality fuel use remains abundant, even in households using biogas. Continued promotion of the construction of biogas installations is advisable, but additional policies are needed to ensure higher quality heating energy supply and cleaner uses of biomass fuels.

1. Introduction

Due to limited access to modern energy services, the rural population in the developing world largely relies on low quality fuels such as dung, crop residues, fuel wood and coal for cooking and heating purposes (e.g., Heltberg, 2003a; Kaygusuz, 2011; OECD/IEA, 2010). These fuels require extensive amounts of time and effort for their collection and preparation, and their use is detrimental to indoor air quality, negatively impacting human health (Fan et al., 2011; Kaygusuz, 2011; Zhang et al., 2007). They also have substantial environmental effects. Their carbon emissions contribute to global warming and, in the case of firewood, energy use contributes to forest degradation (Akpalu et al., 2011). Improving the access to affordable, clean energy sources therefore is a key component of sustainable development for rural areas in the developing world, having multiple co-benefits for development, human health, environment and climate change (AGECC, 2010).

The promotion of household biogas installations is one of the strategies pursued for more sustainable energy use in rural areas of developing countries (Bond and Templeton, 2011; Kaygusuz, 2011). Although there is strong consensus that biogas will contribute to sustainable development, there is less clarity on the extent to which it has done so.

One stream of research has focused on assessment of the extent to which biogas contributes to one or more sustainability effects, e.g., greenhouse gas or health damaging emissions. However, these studies typically assume that (1) biogas will not add to the household energy balance, but replace an equal amount of

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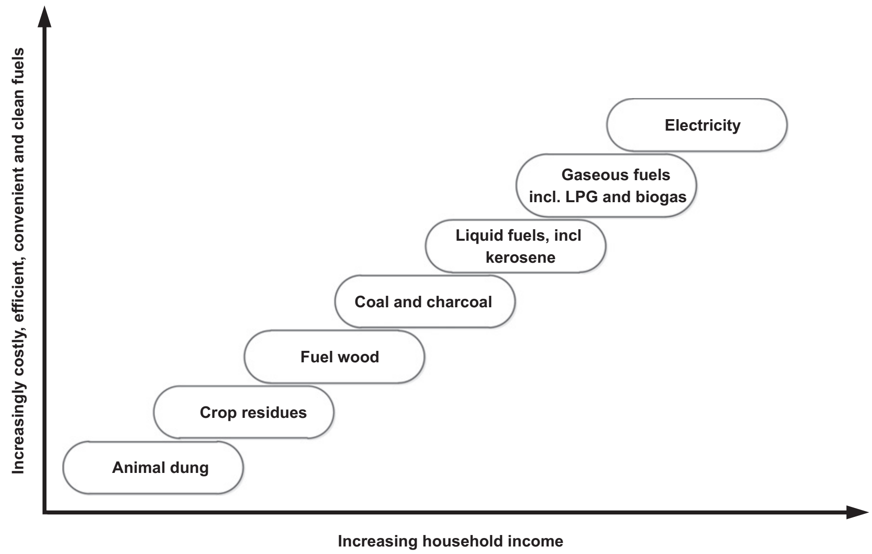

Fig. 1. The 'energy ladder'.
Source: based on (Bruce et al., 2002; Smith et al., 1994).

useful energy as previously supplied by other fuel types, and (2) that it will be coal and/or traditional biomass that are replaced (e.g., Dong and Li, 2010; Feng et al., 2009; Yu et al., 2008; Zhang et al., 2007; Zhang and Wang, 2005). This assumption is often not sustained by empirical data, and is likely to be overly optimistic, for two reasons. First, the rural poor not only desire better quality fuels but also higher consumption levels of energy (Eckholm, 1975; Hiemstra-van der Horst and Hovorka, 2008). Second, low income households continue to have a strong incentive to minimize fuel expense and reduce the consumption of costlier, high quality fuels rather than that of less costly low quality fuels (Smith et al., 1994). Biogas may replace other fuel types, but might also lead to additional energy consumption.

Another stream of literature concerned with the contribution of biogas to sustainable development, has employed the concept of the "energy ladder" (see Fig. 1), which ranks fuels from 'worst' to 'best' in terms of cost, cleanliness, convenience etc. (Arnold et al., 2006; Hiemstra-van der Horst and Hovorka, 2008; Smith et al., 1994; Sovacool, 2011). The rural poor are restricted in their fuel choices by high prices of high quality fuels and therefore depend on low quality fuels, a condition termed 'energy poverty'. Increasing the access to affordable, clean energy sources, i.e., enabling progress up the "energy ladder", is assumed to catalyse sustainable development. This stream of research focuses on the factors that affect fuel use choices on the household level, and assesses effects in progress along the 'energy ladder'. Such results are hampered because of their uni-dimensional operationalization of sustainability. They lack a specification of how *different* fuels contribute to (solving) *different* dimensions of sustainability. Sustainability is a multi-facetted goal, and different energy types will affect different dimensions to a differing extent.

The main contribution of this paper is to analyse how rural household scale biogas effectively contributes to sustainability, measured across multiple dimensions, and on the basis of empirically determined changes in household fuel consumption patterns. Compared with analyses that focused on individual sustainability effects, the breadth of our approach requires a number of simplifications in our assessment indicators. Our contribution lies not in furthering the understanding of specific sustainability effects, but rather in complementing that knowledge by investigating the comparative strength of effects on different dimensions of sustainability.

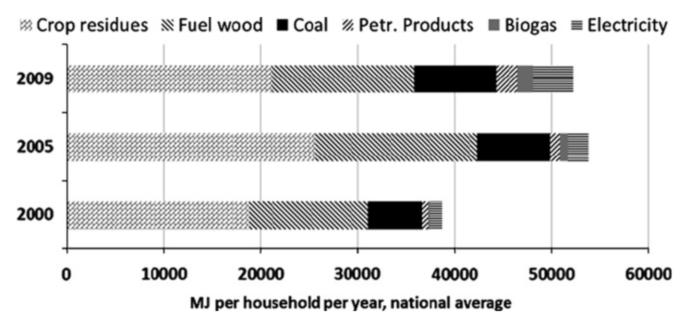

Fig. 2. Rural energy use in China.
Sources: number of households (NBS, 2010b), commercial fuels (NBS, 2010a); biogas (MOA, 2010); non-commercial fuels (CRES, 2010). *Note*: petroleum products include transport fuels.

Rural China is amongst the areas where dependency on low quality fuels persists (Fig. 2). The Chinese government has long had programmes in place to support the construction of household scale biogas digesters (Chen et al., 2010). By the end of 2010, 22.5 per cent of the rural population, or nearly 40 million out of a total of 179 million rural households owned and actively used a biogas digester (MOA, 2010; NBS, 2010b). With the support of biogas digester construction, the government pursues a multitude of goals, i.e., improving household budgets, reducing forest degradation, improving rural living conditions, increasing renewable energy use and reducing GHG emissions (MOA, 2007b). Because of the limitations of earlier assessments, it remains unclear to what extent these different policy targets have been achieved. This paper will accordingly take China as a case for analysis of the contribution of biogas to sustainable development.

The paper is structured as follows. In Section 2 we introduce the Chinese policy background for household scale biogas. In Section 3, we introduce our assessment framework, building on stated goals in Chinese biogas policy. In Section 4 we explain what factors other than the use of biogas may influence consumption levels of other fuel types. Section 5 introduces the study area and method. Results are presented in two parts: Section 6 for fuel use changes and Section 7 for the assessment of the contribution of biogas to sustainability. Section 8 contains the conclusion and we close in Section 9 with a discussion of results and policy implications.