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Preferences for micro-cogeneration in Germany: Policy implications for grid expansion from a discrete choice experiment

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HIGHLIGHTS

- Using choice experiments to investigate preferences for micro-cogeneration products.
- Sample of 411 German homeowners and tenants.
- Heating cost savings are most important for consumers.
- Willingness to pay ranges between 11,000 and 23,000 EUR for micro-cogeneration.
- Market potential is present but institutional barriers restrict use.

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ABSTRACT

Increasing the share of renewable energies requires an extension of grid capacity and additional storage possibilities. Although load shifting has been identified as a key instrument to relieve an overloaded grid, technologies that enable the decentralization of load shifting have hardly penetrated the electricity market. In this paper, a discrete choice experiment is applied to investigate preferences and willingness to pay values for micro-cogeneration, a technology that has huge potential to enhance load shifting, and at the same time reduce costs and CO_2 emissions for heating. Our study includes homeowners as well as tenants to capture the overall market potential. Drawing from a sample of 412 adult Germans, several drivers of willingness to pay for micro-cogeneration are identified such as cost and CO_2 saving potential, contract specifics and a feed-in tariff. The results show that most people would be willing to invest in micro-cogeneration technologies but non-monetary obstacles, such as limited institutional support, hinder investment on a larger scale. Several sources of preference heterogeneity are identified, giving rise to the development of a large variety of products and incentive structures.

1. Introduction

1.1. Status of markets for micro-cogeneration in Germany

Contributing to global efforts to reduce climate change, several governments all over the world have initiated efforts to increase the share of renewable energy [1]. In 2014, electricity from renewable energy sources accounted for about 23% of total electricity production worldwide and its share is continuously growing [2]. Currently, most renewable energy production comes from large hydro power plants. However, it is expected that additional renewable energy capacities will be based mainly on on-shore wind power and photovoltaic solar fields. Unlike conventional electricity generation and hydro power, such sources inherit temporal uncertainties in production. These uncertainties lead to fluctuating electricity availability, requiring new technologies to balance supply and demand (i.e. to minimize short-term differences in supply and demand) [3]. Additionally, electricity grid capacity is currently insufficient to keep up with changes in the power generation portfolio. To cope with these issues, demand and supply side measures are necessary. On the demand side, smart-grid technologies are powerful yet mostly untapped instruments for energy balancing and for reducing the requirements on grid capacity. One example of these smart-grid technologies is the micro-cogeneration of heat and power. The use of micro-cogeneration in family houses allows for an efficient application of fossil and renewable energy sources. As required, users of micro-cogeneration can use power production for their own use or feed

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Nomenclature

A_i	vector with the attribute levels in alternative $i\,(a_{1i},a_{2i},\ldots)$
β	vector of associated parameters
ϵ_i	random component capturing all effects on utility that cannot be described by observed variables
n	respondent
σ	scale parameter
μ	location parameter
ASC	alternative specific constant
CO2SAV	CO_2 savings in%
CSAV	expected cost savings on overall energy costs in%
DUR	contract duration
FIT	feed-in tariff for excess electricity
HEATSYS	gas powered heating system
ICOST	investment costs
ITYPE	type of investment
kW_{el}	kilowatt electric
RPL	random parameters logit
U_i	utility function
V_i	observed part of utility $A_i\beta$
WTP	willingness to pay
z	interaction terms

it into the grid. Combined heat production can then be used locally by users, e.g. for water and space heating [4]. If, however the electricity requirement exceeds what is being generated, extra power can be imported [5]. Local heat stores, e.g. a hot water boiler, can be used by operators or generators for short-term power store. This additional storage capacity reduces demand for balance energy, for example excess electricity from wind power or photovoltaic can be exported by grid operators in micro-cogeneration units. Recent research has shown that using load shifts to optimize energy procurement from micro-cogeneration generates higher financial benefits for utilities compared to alternative load management approaches [6].

1.2. Market development of micro-cogeneration

Several European Union member states have recognized the advantages of micro-cogeneration. Since 2009, micro-cogeneration has been supported by several governments in order to increase system efficiency. For example, the program Ene.field aims to install about 1000 fuel cell micro-cogeneration systems in 12 EU-member states [7]. Consequently, several energy utilities have started the market introduction of micro-cogeneration in the residential sector. However, the current market share of micro-cogeneration in private households is still low [8]. One reason for the low market share can be traced back to a lack of public acceptance of such technologies [9]. Especially decentralized technologies require acceptance and an active participation of the affected users [10]. The scientific literature is mainly silent about consumer perceptions and preferences towards decentralized micro-cogeneration energy solutions. It is unclear which determinants of micro-cogeneration units affect the decision to invest into micro-cogeneration. The lack of scientific knowledge on consumer preferences for micro-cogeneration can be attributed to the complexity of the environmental effects, the design of the product itself, and uncertain benefits to the user. These benefits often depend on (sometimes uncertain) national energy policies.

The benefits of micro-cogeneration for users result from cost savings and additional revenues. These revenues are seasonal but appear constantly [5]. Social welfare effects come from CO_2 reductions due to a higher efficiency of micro-cogeneration and avoided costs of grid operation for balance energy. Effects on efficiency depend on the used energy sources. Compared to conventional external heat and power supply, micro-cogeneration can reduce input of primary energy by around 29% and the losses by around 7% [11]. Micro-cogeneration is particularly applicable for users with a high demand for heat such as multi-family homes, private and public swimming pools and sports associations [4]. However, for the vast majority of end-users with lower intensity of consumption, an individual cost-benefit analysis is required to proof the profitability of micro-cogeneration units [12,13]. Moreover, economies of scale of micro-cogeneration and the further improvement of fuel-cell based micro-cogeneration increase welfare effects in terms of CO_2 savings, efficiency improvements for heat and power consumption, and reductions in costs for balance energy. For example, Guy and Sykes [5] examined widespread application of micro-cogeneration devices in small enterprises and in private households in UK. They used field trials to analyse performance of individual domestic and small commercial micro-cogeneration systems. Regarding domestic use the objective was to identify efficiency improvements and CO_2 savings. The authors examined micro-cogeneration devices using the Stirling technology. One main focus was on the CO_2 performance. The authors found that the CO_2 performance of domestic micro-cogeneration is determined by the ratio of heat to power generated and by various user specific components such as overall efficiency, efficiency of pumps, user settings and behaviour. However, CO_2 savings increase with high demand for heat. Households with consumption of more than 15,000 kWh per year achieve CO_2 savings of 9% [5]. Barker et al. [4] emphasize benefits from applications of micro-cogeneration in terms of efficiency gains and CO_2 savings. The authors conclude that economies of scale are necessary for cost reductions and marketability. Yet, financial support is a precondition for economies of scale.

1.3. Non-market benefits of micro-cogeneration

Although micro-cogeneration units are private goods, some attributes of micro-cogeneration such as the avoidance of grid congestion and the provision of storage capacity have public goods characteristics. Its usage creates positive externalities: The thermal storage capacity of micro-cogeneration units reduces the required amount of balancing energy, and, at the same time, reduces CO_2 emissions [14,15], depending on the prevailing energy mix.[1] If micro-cogeneration units are operated with biogas, additional positive effects might arise. These effects include the substitution of central electricity generation with fossil fuels with local renewable sources and low CO_2 emissions [17]. To measure consumer preferences for attributes of micro-cogeneration units, observed market prices cannot be used. This is because most of these attributes are not traded on markets. A user cannot "buy" a feed-in tariff or CO_2 savings, as these are exogenously given. The majority of studies using non-market valuation techniques to study such effects focus on the preferences of homeowners for building energy efficiency and home heating systems in general. For example, Alberini et al. [18] used a discrete choice experiment to estimate the preferences of homeowners for investments in energy efficiency. The results illustrate subsidies as a main driver for investment decisions. The authors identify uncertainty as a main threat regarding the investment of homeowners in energy efficiency. Ruokamo [19] examined hybrid home heating systems on six different heating alternatives. The results indicated a high acceptance of households for hybrid home heating systems dependent on individual attitudes and socio-demographic variables. In particular, living environment, age, income and location of residence affect the choice of home heating systems. In a similar study,

[1] In the year 2015 the average CO_2 emissions in the German electricity sector were 535 g per kWh [16]. With micro-cogeneration every kWh excess power used for heating reduces CO_2 emissions by this amount.