Bio-based and Applied Economics 9(3): 225-240, 2020
DOI: 10.13128/bae-7768

Full Research Article

Investigating determinants of choice and predicting market shares of renewable-based heating systems under alternative policy scenarios

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Abstract. Fostering the uptake of heating technologies based on renewable resources is an important part of the EU energy policy. Yet, despite efforts to promote their diffusion, heating systems based on fossil fuels are still predominant. In order to better tailor energy policies to citizens preferences, it is crucial to collect accurate information on their determinants of heating choices. At this purpose, we adopted a choice experiment and a latent class model to analyze preferences of householders in the Veneto region (North-East Italy) for different heating systems and their key features. We focused on three devices based on biomass and three on fossil fuels, and accounted for technical, economic and environmental characteristics of such systems. Model estimates highlight the presence of substantial preference heterogeneity among the population, which can be partially explained by citizens socio-demographics. We also use model outputs to simulate market shares for heating systems under alternative policy scenarios. Results provide interesting suggestions to inform the design of policies aimed at fostering the adoption of biomass-based heating systems.

Keywords. Ambient heating systems choice, Latent class Model, Market shares, Willingness to pay.

JEL Codes. C01, Q42, Q47.

1. Introduction

Developing a strategy to increase the sustainability of the heating sector is a priority for the European Union, in order to reduce energy imports and dependency and meet the greenhouse gas emission target established under the Paris Agreement. Currently, heating and cooling account for half of the EU energy consumption and 75% of the fuel used in this sector comes from non-renewable resources (European Commission, 2016).

To tackle such issues, the 2030 Climate and Energy Policy Framework adopted by the European Council in 2014 includes three key targets for 2030: i) a 40% reduction of green-

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Editor: Meri Raggi.

ISSN 2280-6180 (print)
ISSN 2280-6172 (online)

house gas (GHG) emissions compared to 1990 levels, ii) a 27% share of renewable energy in gross final energy demand and iii) a 27% increase in energy efficiency (European Council, 2014). The targets for renewables and energy efficiency were revised upwards in 2018 at 32% and 32.5% respectively. Member States are obliged to adopt integrated National Climate and Energy Plans (NECPs) for the period 2021-2030 to define how they plan to achieve such goals. Member States submitted their draft plans in 2018 and final plans must be submitted by the end of 2019. Italy, in its draft plan, set the targets of a 33% reduction of GHG emissions compared to 2005 levels and a 30% share of renewable energy on final consumption to be achieved by 2030 (Italian Government, 2018). In 2017, the values for the two targets were 18% and 17% respectively. Thus, as emphasized in the EU Country Report 2019 (European Commission, 2019), further efforts are needed to ensure the achievement of 2030 objectives. Among the specific targets set by the plan, there is an annual increase of 1.3% of renewables share in the sector of residential heating and cooling. To achieve such target – among other measures – the plan aims to promote an active role by citizens on the energy demand market and the uptake of micro-generation technologies based on renewables. As such, installation of renewable based residential heating systems in new buildings and replacement of fossil fuel technologies in existing ones plays a crucial role in the energy system transition. To entice the active participation of citizens, it is important to collect information on their heating preferences, in order to retrieve determinants of heating choices.

Information about heating preferences can be collected via choice experiment, an increasingly popular method for stated preferences analysis. For example, Rommel and Sagebiel (2017) investigated preferences of German homeowners for micro-cogeneration units for residential use. Their results suggest how householders have a strong interest in adopting such technologies, with willingness to pay (WTP) values ranging from 11.000 to 23.000 Euros. Features of micro-cogeneration products, as well as socio-demographics characteristics of houseowners, were found to substantially affect their WTP. Scarpa and Willis (2010) investigated WTP for the adoption of different renewable micro-generation technologies in the UK. Specifically, they focused on solar photovoltaic, micro-wind, solar thermal, heat pumps, biomass boilers and pellet stoves. Their results suggest that householders are willing to adopt such technologies, but for most of them WTP values do not cover capital cost. A similar study was carried out by Su et al. (2018) in Lithuania. Authors found householders to prefer solar energy-based technologies over the other renewable based ones. Claudy et al. (2010) also estimated consumers' WTP for different microgeneration technologies, namely micro wind turbines, wood pellet boilers, solar panels and solar water heaters. The study showed how WTPs vary substantially among different technologies and how consumers attitudes and beliefs about the technologies significantly influence their WTPs. Rouvinen and Matero (2013) focused on preferences towards different types of heating systems (based on fuel used) and examined the role of system features on householders' choices in Finland. Investment cost was identified as the most impactful attribute on householders' decisions, but non-monetary attributes played a significant role as well. Results also provided evidence of preference heterogeneity, partially linked to individuals' characteristics. Similarly, Michelsen and Madlener (2012) analyzed the influence of sensitivity to different heating systems' attributes on homeowners' adoption decision. Their findings suggest that importance attached to different attributes affects technological features choice: for example, people focused on energy saving are more likely to adopt condensing boilers with thermal support, while consumers attaching a strong value to use of renewables prefer pellet-fired boilers. Furthermore, they found socio-demographics and spatial factors to affect preferences. Ruokamo (2016) explored homeowners' attitudes towards innovative hybrid home heating systems, described in terms of fuel used and key features, such as costs, comfort of use and environmental impact. The author found that such technologies are generally well accepted by houseowners and that their preferences are strongly affected by socio-demographic characteristics. Yoon et al. (2015) compared householders' WTP for district heating and individual heating. While they found citizens to be generally willing to pay more for district heating, substantial differences emerged when accounting for preference heterogeneity: consumers with higher income and education were found to prefer district heating, while those more concerned about costs were willing to pay more for the individual one.

In this paper we present the results of a choice experiment aimed at eliciting householders' preferences towards different heating systems in the Veneto region (Italy). Specifically, we focus on six different heating systems, three based on renewables (chip wood, firewood and wood pellet) and three on fossil fuels (methane, oil and LPG).

Veneto is a fairly populated region (almost five million residents) characterized by air pollution mainly related to high road traffic in all main cities and by the presence of large industrial districts in several sectors, such as tanning, cement production and furniture manufacturing. When accounting specifically for carbon dioxide emission, the residential impact is substantial as well, around the 20% of total emissions (ARPAV, 2015).

To decrease the negative impact of residential sector on the production of greenhouse gases, since 2014 the regional authority supports the purchase of biomass-based heating systems by annually allocating financial subsidies (up to €1,600 for stoves and €5,000 for boilers). Such policy, however, seems to only marginally meet the expectations of the population, in terms of fostering the adoption of such technologies. For example, in 2018 only 29 citizens applied for the funding and 25 requests were approved, for a total of around €55.000, out of €500,000 allocated policy budget. In 2019 the number of requests was higher (76, of which 66 approved) but again most of the policy budget was not used (around €120,000 allocated out of a budget of €500,000)[1]. Thus, a better understanding of underlying factors motivating householders to stick with a fossil fuel system or to switch to a renewable one, is of crucial to reach the goals of the energy transformation process in the region.

Building on the evidence provided by the literature on how preferences towards different heating systems are highly heterogeneous and on how socio-demographics play an important role in such variability, we adopt a Latent Class approach and use socio-demographic characteristics of respondents to predict probability to belong to different classes. This approach allows to: i) identify different segments of the population according to socio-demographic characteristics; ii) explore how preferences towards different heating systems and their features vary across segments. We then use the estimates of such model to predict market shares for alternative heating systems within two policy scenarios, considering/based on a reduction of: i) investment costs for biomass fueled heating systems; ii) operating costs for biomass-based technologies. Both simulated scenarios are in line with the policies implemented by the Veneto region, the idea being that our empirical results may become useful

[1] Data retrieved from https://www.regione.veneto.it/web/ambiente-e-territorio/rottamazione-stufe-bando-2019.

to better tailor the features of such policies to the population of the region. Reduction of investment cost is a commonly adopted policy to foster use of renewable based technologies, such as the subsidies provided by the Veneto region. Reduction of operating costs is a possible effect of targeted policies as well (e.g. subsidies on fuel purchase).

The objective of our study is twofold: on one hand to investigate how socio-demographic characteristics influence citizens choice of heating systems, in order to gain insights on the determinants of adoption of renewable based technologies; on the other, to identify which, among a set of possible policy interventions, can be more effective in terms of fostering the diffusion of such technologies among the population.

The remainder of the paper is organized as follows: section 2 describes data collection (sampling procedure, survey design and administration); section 3 formally describes the econometric approach; section 4 reports the results of our study and section 5 draws its conclusions.

2. Data collection and survey

This section reports a succinct description of sampling procedure and survey. Further details can be found in Franceschinis et al. 2016, 2017.

Data were collected with the support of a market research firm via a web-based survey addressed to a sample of householders of the Veneto region. We used a random sample of householders, stratified on the main socio-demographics (age, education, gender, place of residence). A total of 1,557 questionnaires were collected, out of which 1,451 were complete and used for the analysis. The questionnaire was structured in five sections. The first focused on heating system and energy resources currently used by respondents. The following section included the choice experiment, which is described in detail below. The third section included follow-up questions about the choices made in the previous section. The fourth section presented attitudinal questions related to respondents' psychological traits. The last collected socio-demographic information.

The choice experiment involved a hypothetical scenario in which respondents were asked to select the heating system they would adopt if they had to renovate their current one among a set of alternative options. The heating systems presented to respondents were six, three based on biomass (firewood, chip wood and wood pellet) and three on fossil fuels (methane, LPG and oil). Each alternative system was described in terms of six attributes: i) investment cost, ii) investment duration, iii) annual operating cost, iv) CO_2 emissions, v) fine particle emissions and vi) required own work. The respective levels were system-specific and are reported in Table 1. Investment cost is the cost for purchasing and installing the heating system. Possible public incentives were not accounted for in defining the levels of the attribute. Investment duration refers to the lifespan of the heating system, from purchase to dismantling. Operating costs include fuel price, maintenance costs and electricity costs for those systems that need it to work. CO_2 emissions and fine particles emissions refer to the quantity of CO_2 and fine particles released by the fuel combustion processes. To facilitate the evaluation of CO_2 emissions levels, respondents were informed that 1,000 kg of CO_2 corresponds to the emissions from driving 6,000 km in a new generation car. To illustrate fine particles health impacts, respondents were informed that "it has been estimated that if annual fine particle emissions for one house are 2,000 g, then

Table 1. Choice Experiment attributes and levels.

Attributes	Firewood	Chip wood	Wood Pellet	Methane	Oil	LP Gas
Investment cost (€)	9,500; 11,000; 12,500	11,500; 13,000; 14,500	13,000; 15,000; 17,000	4,000 4,800; 5,600	4,500; 5,500; 6,500	4,000; 5,000; 6,000
Investment duration (y)	15; 17; 19	17; 20; 23	16; 19; 22	16; 18; 20	16; 18; 20	14; 17; 20
Operating cost (€/y)	1,200; 2,000; 2,800	2,000; 2,800; 3,600	2,500; 3,750; 5,000	4,000; 5,500; 7,000	6,000; 8,000; 10,000	9,000; 12,500; 16,000
CO_2 Emissions (kg/y)	150; 225; 300	300; 375; 450	375; 450; 525	3,000; 3,750; 4,500	3,900; 4,575; 5,250	3,525; 4,125; 4,725
Fine particle emissions (g/y)	4,500; 6,000; 7,500	2,250; 3,750; 5,250	750; 1,500; 2,250	15; 30; 45	150; 450; 750	15; 30; 45
Required own work (h/m)	5; 10; 15	1; 2; 3	1; 2; 3	-	0.5; 1; 1.5	0.5; 1; 1.5

the total emissions of 10,000 similar houses cause one premature death per year". Finally, required own work refers to the time required to ensure the faultless operation of the heating system (e.g., cleaning and handling fuel loads). The choice of attributes and their levels was based on earlier studies and on feedback from experts. The annual operating cost and CO_2 and fine particle emissions were computed using as reference the energy consumption of an average detached house with a living area of 120 m^2.

The experimental design adopted in the study was an efficient availability design (Rose et al., 2013), according to which only three alternatives were shown in each choice task. The combination of levels that appeared in each scenario was defined with three different sub designs, namely near orthogonal, D-efficient (Scarpa and Rose, 2008; Rose and Bliemer, 2009) and serial designs. For the latter, an orthogonal design was used for the first respondent. After the choice sequence was completed, a multinomial logit model was estimated in the background and statistically significant parameters were used as priors to generate an efficient design. This process continued after each respondent and priors were continuously updated to generate a gradually more efficient design. Overall, the design generated 60 choice scenarios blocked in six groups, so that each respondent faced 10 of them. The sample was split so to have the same number of respondents assigned to the three different sub designs. An example of choice scenario is reported in Table 2.

3. Econometric approach

In our study we estimated a latent class model to investigate variation of tastes towards heating systems types and their features among the householders of the Veneto

Table 2. Example of choice scenario.

Attributes	Wood Pellet	LP Gas	Firewood
Investment Duration (years)	19	20	19
Fine particles emissions (g/year)	2,250	15	7,500
CO_2 emission (kg/year)	375	3,525	150
Required own work (hours/month)	1	1	15
Investment cost (€)	17,000	5,000	12,500
Operative cost (€)	3,750	9,000	1,200
Your choice	○	○	○

Region. The model is based on the Random Utility Theory (Luce, 1959; McFadden, 1974), according to which a respondent *n* facing a set of *J* mutually exclusive alternatives has utility U_i for alternative *i* as a function of attributes X_k, so that:

$$U_{ni}=\beta x_{ni}+\varepsilon_{ni} \quad (1)$$

where ε_{ni} is the unobserved error assumed to be i.i.d. extreme value type I.

To account for heterogeneity in sensitivity to attributes X_k, we adopted a latent class model. Such model assumes the existence of *C* classes of respondents, where *C* is exogenously defined by the analyst, based on information criteria indexes. Preference vary across classes but are homogeneous within them. As the classes are latent, an equation explaining the probabilistic assignment of individual *n* into class *c* needs to be defined. Using a logit formulation for the class allocation model, with Z_n being a vector of socio-economic variables and θ_c a vector of estimated coefficients, the probability that individual *n* belongs to segment *c* is given by (Bhat, 1997):

$$\pi_{nc} = \frac{\exp(\theta_c' Z_n)}{\sum_{c=1}^{c=C} \exp(\theta_c' Z_n)} \quad (2)$$

Specifically, the variables we used in Z vector are: i) age, ii) education, iii) income, iv) currently owning a biomass-based heating system.

Then, the probability that individual *n* chooses alternative *i*, conditional on belonging to class *c*, takes the logit form (Hensher and Greene, 2003):

$$\pi_{ni|c} = \frac{\exp(\beta_{nc}' X_i)}{\sum_{j=1}^{j=J} \exp(\beta_{nc}' X_j)} \quad (3)$$

Where X_i represents the vector of attributes associated with each alternative and β_{nc} the vector of estimated coefficients for class *c*.

The estimated parameters of the latent class model were used to simulate the market shares of different heating systems under different policy scenarios. Specifically, the scenarios involve reductions of investment cost (ranging from none to 50% reduction) and operational costs (same levels as previous case) for biomass-based heating systems. We computed choice probabilities in each scenario with the logit formula described in Equation 3, by including in it estimated coefficients β_{nc} and by varying the levels of investment and operational costs according to the reduction scenarios.

4. Results

This section reports the results of our study. In the first part of the section the estimates of the latent class model are presented, while the second part focuses on the policy scenarios.

4.1 LC model estimates

The first step of our modelling approach involves the identification of the optimal number of classes. As suggested by the literature (Hurvich and Tsai, 1989; Nylund et al., 2007), we referred to the AIC and BIC information criteria, which both favour a specification with 4 classes (Table 3). Class membership probabilities are 23% for class 1, 36% for class 2, 16% for class 3 and 25% for class 4 (Table 4). Results of latent class model with four classes are reported in Table 2[2]. The table also reports WTP values for heating systems features, which were computed with respect to the investment cost.

To class 1 are more likely to belong older individuals with low income and education, who currently do not own a biomass-based heating system. Such class exhibits a strong preference towards methane-fuelled technologies with seemingly no interest in biomass-based ones. As it concerns the attributes, it can be noticed how members of this class are very sensitive to installation and operational costs, which is consistent with their feature of individuals with low income. This class seems also sensitive to technical features of heating systems, and it shows a preference for systems with a long duration (WTP value of €0.38 for each additional year of duration) and which require low amount of time for maintenance (€0.27 to avoid an hour of work per month). Emissions, instead, do not seem to affect choices of members of this class.

Moving to class 2, to this class are more likely to belong younger individuals with high education and income who currently do not possess a biomass-based technology.

Table 3. Information criteria for alternative model specifications.

Number of classes	Number of parameters	LL	AIC	BIC
1 (MNL)	11	-15,713	31,448	31,506
2	28	-15,081	30,218	30,367
3	44	-15,017	30,122	30,356
4	60	-14,894	29,908	30,227
5	76	-14,886	29,924	30,328

[2] A part of these results was included in the report "Veneto 100% Rinnovabile: fotografia e prospettive" by the Interdepartmental Centre Giorgio Levi Cases for Energy Economics and Technology (University of Padova), available at http://levicases.unipd.it/wp-content/uploads/2019/11/Relazione-finale.pdf

Table 4. LC model results.

Class size	Class 1 23%		Class 2 36%		Class 3 16%		Class 4 25%	
	Estimate	WTP	Estimate	WTP	Estimate	WTP	Estimate	WTP
Class membership function								
Intercept	**0.16**		0.24		-0.11		-0.07	
Age	**0.31**		-0.31		0.12			
Degree	**-0.22**		0.43		-0.23			
Income	**-0.15**		0.32		0.02			
Owning a biomass fuelled system	**-0.22**		-0.11		0.19			
Heating system features								
Investment cost	**-0.41**		-0.89		-0.18		-0.49	
Operational cost	**-0.38**		-0.95		-0.31		-0.46	
Investment duration	**0.16**	**0.38**	0.34	0.38	**0.28**	**1.58**	**0.17**	**0.35**
Required own work	**-0.11**	**-0.27**	-0.24	-0.27	0.09	0.50	**-1.41**	**-2.87**
CO_2 emissions	-0.01	-0.03	**-0.73**	**-0.82**	**-0.06**	**-0.36**	**-0.02**	**-0.04**
Fine particle emissions	0.04	0.10	**-0.28**	**-0.31**	-0.05	-0.25	**0.01**	**-0.01**
Heating system type								
Firewood	2.00		4.99		1.89		1.55	
Chip wood	-3.96		1.94		0.99		1.21	
Wood pellet	0.42		10.88		0.46		4.20	
Methane	**4.81**		7.65		0.19		6.29	
Oil	**-0.39**		2.14		-0.04		-1.26	

Note: Coefficients statistically significant at 95% in bold. WTP values were computed with respect to the investment cost.

As it concerns preferences towards different types of heating system, it can be noticed how members of such class show a strong interest in biomass fuelled system, especially those based on wood pellet. This suggests that such class has a strong potential in terms of switching from a fossil fuel-based system to a biomass one. This seems corroborated by the high sensitivity to carbon dioxide and fine particles emissions of members of this class, which are those willing to pay the most to avoid them among all classes (€0.73/kg/year for CO_2 and €0.28/g/year for fine particles). At the opposite, in this class there seems to be no concern about technical features of heating systems.

To class 3, instead, are more likely to belong older individuals who currently own biomass-based heating system. As in the previous class, there seems to be a strong interest in biomass technologies, but in this case, firewood is the preferred fuel. As it concerns heating systems features, members of this class seem to strongly appreciate technologies with long investment duration (€1.58 for each additional year, largest value among all classes) and low emissions of carbon dioxide (€0.36 to avoid a kilogram per year).

Finally, members of class 4 (the baseline class) seem to be interested mainly in methane-based systems and in those fuelled by wood pellet. They also have a strong aversion to oil-based technologies. As it concerns systems' features, they seem interested in low maintenance requirements and to a lesser degree to avoiding emissions, with low WTP values (€0.04/kg/year to avoid CO_2 and €0.01/g/year to avoid fine particles).

4.2 Market shares for different heating systems in alternative policy scenarios

In this sub-section we report results of market shares simulations for different heating systems in two sets of policy scenarios: i) reduction of investment cost for biomass fuelled heating systems, specifically none, 10%, 20%, 30%, 40% and 50%; ii) reduction of operating costs for biomass based technologies (same range as above). In the first part of the sub-section (4.2.1) we present the average market shares weighted by class size for different heating systems; in the second (4.2.2) we report the shares for biomass technologies within each class.

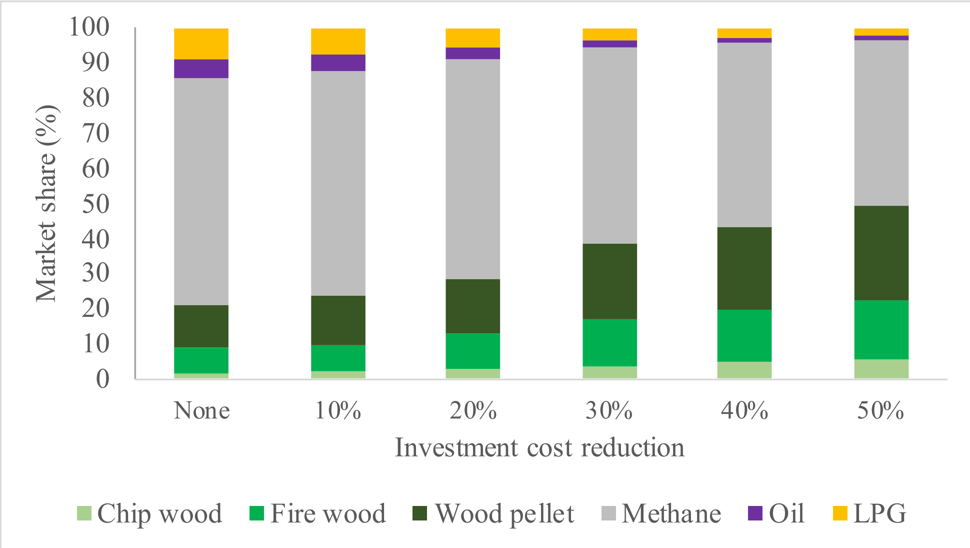
4.2.1 Average market shares in the investment cost reduction scenarios

Table 5 and Figure 1 illustrate weighted average market shares for different heating systems under the investment cost reduction scenario. In the baseline scenario, i.e. no investment cost reduction, most of the population would choose a methane heating system to replace the current one (64.40%), followed by wood pellet (12.61%), LPG (8.82%), firewood (7.35%), oil (5.39%) and chip wood (1.23%). Moving to the 10% reduction scenario, it can be noticed how shares for biomass fuelled technologies slightly increase (around 1% for each system). A 20% reduction seems to trigger a stronger response, with an increase of around 3% for wood pellet and 1.5% for the other biomass-based systems compared to the 10% reduction scenario. In the 30% reduction scenario the share for biomass-based systems further increases, in particular for wood pellet technologies, with a share of around 21% compared to the 12.61% of the baseline scenario. The fourth scenario (40% reduction), instead, does not show substantial differences compared to the previous one. Finally, in the last scenario (50% reduction) around 30% of citizens would choose a wood pellet fired system, around the 17% a firewood one and around the 5% a chip wood one. Overall, in such scenario, nearly half of the population would choose to adopt a bio-

Table 5. Average market shares under the investment cost reduction scenarios.

	Investment cost reduction					
Heating system	None (baseline)	10%	20%	30%	40%	50%
Chip wood	1.23	1.83	2.69	3.21	4.55	5.49
Firewood	7.35	7.90	10.32	13.86	14.93	16.59
Wood pellet	12.61	13.94	15.21	21.36	23.79	26.91
Biomass total	21.19	23.67	28.22	38.43	43.27	49.00
Methane	64.60	63.66	62.49	55.91	52.32	47.33
Oil	5.39	4.84	3.53	2.31	1.70	1.21
LPG	8.82	7.84	5.76	3.36	2.71	2.46
Total	100.00	100.00	100.00	100.00	100.00	100.00

Figure 1. Average market shares under the investment cost reduction scenarios.



mass-based system. The overall increases of the share of biomass-based systems compared to the baseline scenario are: 2.5%, 7%, 17.2%, 22% and 28% for the alternative investment cost reductions.

4.2.2 Average market shares in the operational costs reduction scenarios

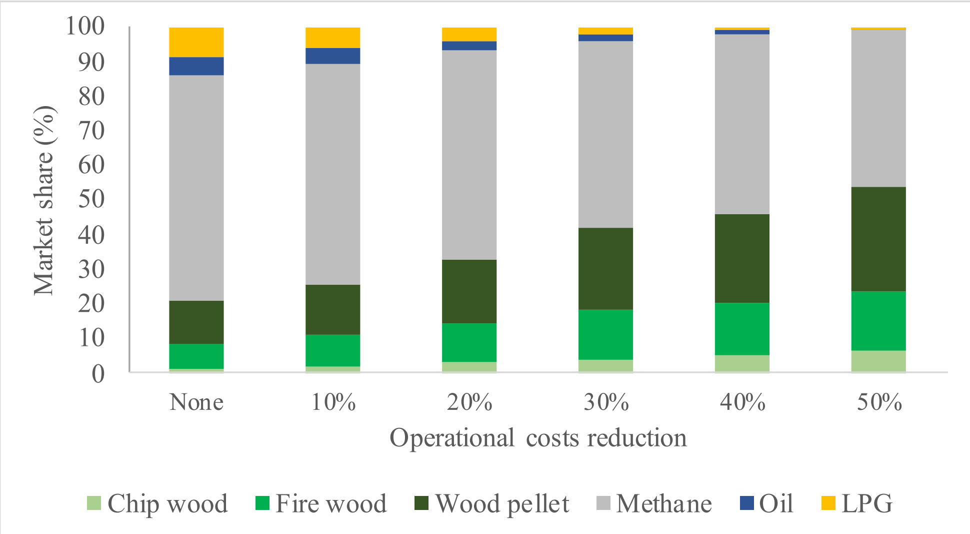
Table 6 and Figure 2 report the estimated average shares under the alternative operational cost reduction scenarios. Firstly, it is of interest to notice how reducing operational costs seems to have a stronger effect in terms of increasing biomass systems market shares compared to the reduction of investment cost. This seems true in each scenario (i.e. for each magnitude of the reduction) and is particularly evident in the 50% reduction scenario, under which the overall biomass technologies share is around 54% for operational costs reduction and 49% for investment cost reduction. In terms of fostering diffusion of biomass fired systems, this seems to suggest how policies aimed at decreasing operational costs for citizens may be more effective than those providing a reduction of the investment cost.

By looking more closely at the operational costs reduction scenarios, it can be noticed that, similarly to the previous scenario, a 10% reduction does not lead to a substantial increase in the shares of biomass technologies (between 1% and 2% increase for each system). A 20% reduction has an only slightly stronger effect, with an increase of about the 3% for biomass systems shares compared to the previous scenario. A similar relative increase is also shown for the 30% and 40% reduction scenarios. Finally, in the last scenario there is a substantial increase in the shares for biomass technologies, especially as it concerns wood pellet, which would be chosen by around the 30% of the population. Overall, it seems that a reduction of the operational costs would strongly favour the dif-

Table 6. Average market shares under the operational costs reduction scenarios.

	Operational costs reduction					
Heating system	None (baseline)	10%	20%	30%	40%	50%
Chip wood	1.23	2.11	3.37	3.88	4.91	6.11
Firewood	7.35	8.65	11.21	14.65	15.32	17.71
Wood pellet	12.61	14.99	18.07	23.16	25.89	29.94
Biomass total	21.19	25.75	32.65	41.69	46.12	53.76
Methane	64.60	63.19	60.66	54.08	51.80	45.19
Oil	5.39	4.65	2.60	1.71	0.98	0.46
LPG	8.82	6.41	4.09	2.52	1.10	0.59
Total	100.00	100.00	100.00	100.00	100.00	100.00

Figure 2. Average market shares for under the operational costs reduction scenarios.



fusion of wood pellet systems and only to a lesser degree the diffusion of other biomass-based systems. This may be due to higher operational costs of pellet fired heating systems, compared to other biomass ones.

4.2.3 Market shares in the investment cost reduction scenarios within each class

In this section we move from the population-level picture to a class-specific analysis, to explore how preference heterogeneity influences the diffusion of biomass heating systems. Specifically, we report and discuss probabilities to choose a biomass-based technology as replacement of the current one within each class in different policy scenarios.

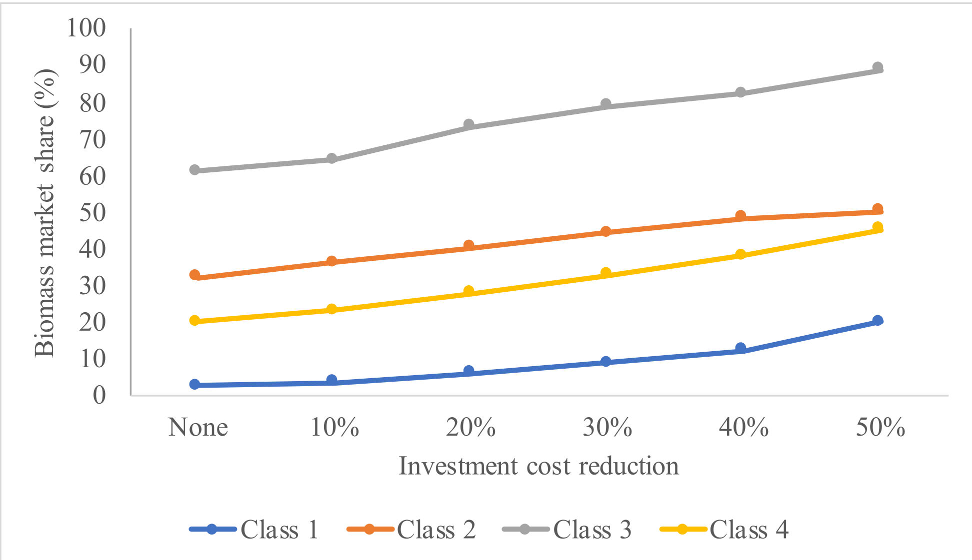
Starting from class 1, Table 7 and Figure 3 show how in class 1 the market share for biomass devices in the baseline scenario is extremely low (2.60%). Such value is consistent with the profile illustrated in Section 4.1, which highlighted how members of this class are characterized by little interest in biomass technologies and absence of sensitivity to carbon emissions. Moving to the cost reduction scenarios, their effect on adoption probability seems limited. Only in the 50% reduction scenario there seems to be a substantial increase in the biomass share (8% increase compared to the 40% reduction scenario). It seems that a very strong incentive is needed to foster diffusion of renewable based systems in this class.

Moving to class 2, the share for biomass devices in the baseline scenario equals 32.11%. Such results – together with the LC estimates – suggest that this class includes individuals who currently own a fossil fuel fired heating system and around one third of them would switch to a biomass fuelled one, even with no cost reduction. This seems to corroborate the potential of this class in terms of increasing the diffusion of renew-

Table 7. Class-specific biomass systems market shares under the investment cost reduction scenarios.

Class	Investment cost reduction					
	None (baseline)	10%	20%	30%	40%	50%
Class 1	2.60	3.39	5.91	8.66	12.11	19.99
Class 2	32.11	36.11	40.18	44.18	48.12	50.08
Class 3	61.16	64.12	73.18	78.81	82.18	88.88
Class 4	19.98	23.11	27.61	32.81	38.11	45.18

Figure 3. Class-specific biomass systems market shares under the investment cost reduction scenarios.



able based technologies across the population. As for the previous class, the effect of the investment cost reduction seems limited. In this case, however, the low effect may be linked to the high income of its members, that could make them less sensitive to costs.

Class 3 exhibits the highest biomass system adoption probability in the baseline scenario (61.6%). Overall, this class seems characterized by individuals that currently use a biomass system and show a high probability of choosing one of the same kind as replacement. Importantly, this class seems to be strongly affected by cost reduction, with an around 28% increase of the biomass devices share between the baseline and the 50% reduction scenario. This might be due to the low income of members of this class.

Finally, biomass systems share in class 4 equals 19.89% in the baseline scenario and 45.18% in the 50% reduction one, thereby suggesting a high sensitivity to investment cost reduction.

4.2.4 Market shares in the operational costs reduction scenarios within each class

Table 8 and Figure 4 report market shares within each class in the operational costs reduction scenarios. By comparing results with those reported in the previous section, it is interesting to notice how class 2 and 3 are affected more strongly by operational costs reduction, while classes 1 and 4 are affected more by investment cost reduction. This seems to be related to different sensitivity to the two costs highlighted in Section 4.1: classes 2 and 3 are more sensitive to operational costs, and as such reducing it has a stronger effect in such classes, while the opposite is true for classes 1 and 4. For example, in class 1, at a 50% reduction the share is around 15% for operational costs and 20% for investment cost. At the opposite, in class 3 the share in 5% higher in the case of operational cost reduction.

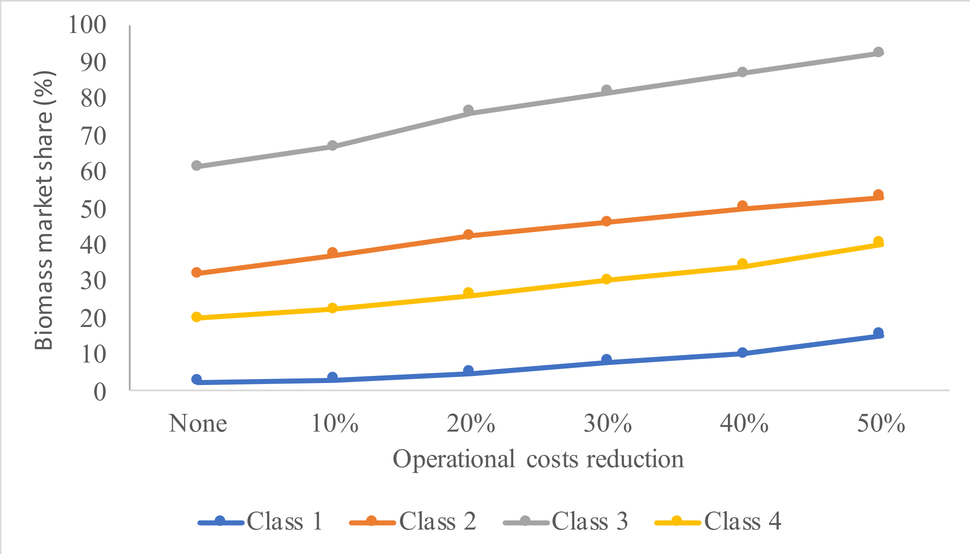
5. Discussion and conclusions

In the light of the importance of increasing the sustainability of the residential heating sector, it is crucial to inform energy policies with an accurate knowledge of the determinants of citizens heating choices. To this purpose, we designed a choice experiment aimed at investigating preferences towards heating systems and their features among the citizens of the Veneto region. We analysed choice data by means of a latent class model and we used the estimates to forecast market shares for different heating systems under alternative policies scenarios.

Table 8. Class-specific biomass systems market shares under the operational costs reduction scenarios.

Class	Operational costs reduction					
	None (baseline)	10%	20%	30%	40%	50%
Class 1	2.60	3.11	4.88	7.91	10.12	15.18
Class 2	32.11	37.14	42.24	46.11	49.88	53.11
Class 3	61.16	66.89	76.11	81.56	86.88	92.21
Class 4	19.98	22.41	26.22	30.33	34.16	40.11

Figure 4. Class-specific biomass systems market shares under the operational costs reduction scenarios.



The results of our study suggest how householders' preferences towards different heating systems and their features are strongly heterogeneous and how such variability can be partially explained by householders socio-demographic characteristics. Such findings support those of previous studies of the energy literature (e.g. Yoon et al., 2015, Ruokamo, 2016). Importantly, our estimates highlight the presence of population segments which seem to have a strong potential in terms of switching from a fossil fuel system to a renewable-based one. To this segment are more likely to belong individuals who already own a biomass-based heating systems and young individuals with high income and education level. At the opposite, our results highlight the existence of segments of the population with low interest towards the adoption of renewable-based technologies. Such segments are characterized by individuals with low income and education who currently own a fossil fuel system.

The simulations of policy scenarios allowed us to retrieve some important information about the efficiency of different policy measures in terms of fostering the diffusion on biomass technologies. Overall, we found that measures aimed at reducing operational costs for householders may induce a broader uptake of biomass appliances compared to those which target investment cost, even if the opposite is true in some segments of the population. This is particularly important in the context of the Veneto region, where subsidies for investment cost are currently in place and they seem to be only partially successful in nudging citizens towards the adoption of biomass-based appliances. We also found that only a large reduction of costs (i.e. 40% or 50% reduction) has a substantial effect on the increase of biomass systems shares, in classes with low interest in such technologies. This suggests that current incentives provided by authorities may not be enough to entice such segments of the population to switch from a fossil fuel to a biomass-based technology.

Acknowledgments

The research was funded by Interdepartmental Centre Giorgio Levi Cases for Energy Economics and Technology (University of Padova), "Sustainability of introduction of pellet based heating systems in a mountain area".

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