



# Consumer acceptance of the energy transition in Switzerland: The role of attitudes explained through a hybrid discrete choice model

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## ABSTRACT

While several countries progress in the energy transition, the social acceptance of new infrastructures becomes increasingly important. We focus on market acceptance, and study the preferences of Swiss households with respect to selected energy sources used for electricity generation. By applying a hybrid discrete choice model with latent variables on stated preference data, we assess households' preferences with respect to the price, origin, and reliability of their electricity supply, and evaluate the impact of demographic, behavioural, and attitudinal drivers thereon. Latent variables representing attitudes allow us to explicitly model psychological traits otherwise unobservable from the data, evaluate their impact on individual choices, and connect them with demographic or behavioural variables. We find that households evaluate variations in the price and reliability of supply differently, depending on the energy source used. Environmental concern is associated to a stronger interest in a generic 100% renewable-based supply, informed optimism to a higher acceptance of nuclear generation. Energy illiteracy and environmental-friendly habits are more frequent among environmentally conscious households, less so among the informed optimists. Measures to foster energy literacy and ensure transparency of energy supply contracts are recommended in order to elicit or maintain consensus, and achieve the desired energy policy goals.

## 1. Introduction

In the context of international climate change mitigation efforts several countries are investing to decarbonize their electricity systems. Besides presenting technical and financial problems, this massive restructuring also poses the challenge of social acceptance of new projects, technologies, and commercial options (European Commission, 2018; Stadelman-Steffen et al., 2019).

Social acceptance is a multifaceted problem (Batel, 2020). So far, it has mainly been explored by considering the three intertwined dimensions of socio-political, community, and market acceptance (Wüstenhagen et al., 2007) and investigating the psychological, cognitive, and contextual factors driving acceptance among citizens or consumers (Huijts et al., 2012). This analysis focusses on the dimension of the market acceptance of the energy transition: we consider individuals as consumers, and investigate the choices they make on the retail electricity market and the factors that influence their decisions. More precisely, we study the preferences of Swiss households towards alternative electricity supply contracts based on different primary energy sources,

and the role of demographic, behavioural, and attitudinal drivers.

We recognize that both the political and institutional setting of a country, and the structure of its energy system influence consumer preferences. Indeed, they define the reference scenario against which the alternative options are evaluated, and contribute to the formation of attitudinal traits that may induce an inclination or aversion toward specific technologies.

The case of Switzerland is particularly interesting in this respect. The Swiss electric system is already based on low-carbon technologies: nuclear and hydroelectric generation contribute to around 40% and 55% of inland productions (BFE - Bundesamt fuer Energie, 2019). However, nuclear generation will be phased out in the medium term, according to the Swiss "Energy Strategy 2050", and investments in low-carbon generation plants will be needed in order to ensure the security and sustainability of the future energy supply (BFE - Bundesamt fuer Energie, 2018; BFE - Bundesamt für Energie, 2019).

Secondly, although the Swiss retail electricity market has not been completely liberalized yet, several electricity providers have been offering to their captive customers alternative contracts with certified

**Abbreviations:** DC, discrete choice; HDCM, hybrid discrete choice model; LV, latent variable; MNL, multinomial logit; RP, random parameter; WTP, willingness to pay.

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renewable-based or locally sourced electricity for many years, even before the partial market opening (Wüstenhagen et al., 2003; Litvine and Wüstenhagen, 2011). Some retailers have even set a basic renewable-based contract as the default option for their residential customers. Despite not being entitled to choose their electricity suppliers, most households are used to choose among a bundle of alternative contracts characterized by a different generation mix.

Finally, in line with the country's long-standing tradition of direct democracy, Swiss citizens have a direct voice in the evolution of the national energy system. They are indeed entitled to approve or repeal legislative items through referenda that can be called at a national, cantonal, and municipal level. Moreover, they can propose amendments to the federal Constitution through the so-called "popular initiatives", that must be approved in a referendum. Popular initiatives have often been used to participate in the definition of general principles for energy and climate policies; the federal Parliament may respond by means of a direct or indirect counter-proposal, the former also subject to the citizens' approval. In the case of an indirect counterproposal and a repealed initiative, the indirect counterproposal is enacted: this helps to understand why, despite the frequent repeals, policy change is possible.

Eleven federal referenda have been called since 2000 on topics related to the electricity sector, and one might be called in the near future (Table 1). The debate that referenda kindle within society, together with the views expressed by political parties, stakeholders, and institutions, often shape attitudes among the citizens who are invited to take a stance on topics that would otherwise be debated mainly among the industrial and political stakeholders.

The context and the influence of peers and institutions have been recognized as important drivers of attitudes and individual decision-making processes (Ben-Akiva et al., 2012). While accounting for the heterogeneity in individual behaviour already improves model fit, investigating the sources of heterogeneity by including psychological and attitudinal drivers improves the behavioural realism of the analysis and the understanding of consumer behaviour (Abou-Zeid and Ben-Akiva, 2014; Mariel and Meyerhoff, 2016). In a setting characterized by on-going confrontation and mediation among the advocates of different strategies for the evolution of the energy system, individual attitudes may evolve or even polarize, and heavily influence consumer choices. Thus, we decided to investigate the preferences of Swiss household by means of a hybrid discrete choice model (HDCM) with latent variables (LVs). The use of a discrete choice (DC) model allows us to compare alternative energy sources and other features of an electricity supply contract that may matter to the consumers. The inclusion of LVs allows us to explicitly model attitudinal drivers within the DC model, going beyond the description of behavioural patterns that would be obtained through a DC model with latent classes.

Considering attitudes in a model explaining individual behaviour is particularly important in the case of Switzerland, but also increasingly useful in any country that has embraced the energy transition, and where consumers are faced with new supply options.

Our results concerning consumer preferences and their drivers may support both the definition of an energy transition path that kindles the least opposition, and the design of electricity supply contracts that elicit a favourable response. A sound understanding of consumer behaviour, including individual attitudes and their drivers, may help preventing opposition to specific policies and projects, and thus facilitate the achievement of the energy policy goals.

Our contribution develops as follows. Chapter 2 collects the relevant suggestions from the economic literature. Chapter 3 and 4 describe our econometric method, survey, and data. Chapter 5 presents our results, and chapter 6 discusses the resulting policy implications.

## 2. Literature review

Individual preferences toward selected primary energy sources have received increasing attention in the last twenty years, in parallel with

**Table 1**

Federal referenda impacting the electricity market since year 2000.

Year	Title	Object	Outcome
2000	Popular initiative "Solar cent"	The organizing committee asks for the introduction of a tax on non-renewable energy in order to finance new incentives for solar energy.	Repealed
2000	Counter-proposal "Incentives for renewables"	As an alternative to the "Solar cent" initiative, this counter-proposal from the Parliament puts forward a tax on non-renewable energy to foster renewables in general.	Repealed
2000	Counter-proposal "Energy and environment"	As an alternative to the "Energy and environment" initiative (withdrawn), this counter-proposal from the Parliament puts forward a tax on non-renewable energy to foster efficiency in energy use, and finance a reduction of labour taxes.	Repealed
2001	Popular initiative "Taxing energy, not work"	The organizing committee asks for the introduction of a tax on non-renewable energy and large hydro to finance a reduction of the old-age and survivors insurance.	Repealed
2002	Referendum on the new energy market law	The new energy market law provides for the creation of a Swiss transmission system operator, the introduction of regulated third party access for the national electricity transmission grid, and a gradual opening of the retail electricity market. In the optional referendum Swiss citizens are asked to approve or reject the new law.	Repealed
2003	Popular initiative "Electricity without nuclear"	The organizing committee asks for the dismantling of existing nuclear plants 30 years after their commissioning and at the expense of their owners. Imports should moreover exclude electricity generated abroad via nuclear plants or thermal plants without cogeneration.	Repealed
2003	Popular initiative on a "Stop to nuclear" moratorium	The organizing committee asks for: 1) a 10 year ban for new nuclear plants and expansions of the existing ones, 2) the introduction of a mandatory declaration of origin for any electricity import.	Repealed
2015	Popular initiative "Energy tax instead of energy VAT"	The organizing committee asks for the replacement of the VAT on electricity with a variable tax on non-renewable electricity imported to or generated in Switzerland. The amount of the new tax should depend on the environmental impact of the electricity and on the fiscal needs of the Confederation.	Repealed
2016	Popular initiative for a "Green economy"	The organizing committee asks the promotion of a sustainable economy: by 2050 the ecological footprint of Swiss residents, if compared to the world's population, should not exceed the Earth yearly resource limits.	Repealed
2016	Popular initiative for a "Nuclear phase-out"	The organizing committee demands that while progressing towards the implementation of	Repealed

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Table 1 (continued)

Year	Title	Object	Outcome
2017	Referendum on the new law on energy	the Energy Strategy 2050, the Confederation should decommission the existing nuclear plants within 45 years since their commissioning (i.e. faster than in the original Strategy). The new law on energy describes the first implementation package of the Energy Strategy 2050. The main measures concern energy efficiency, the promotion of renewable energies, and the nuclear phase-out. The optional referendum asks Swiss citizens to approve or reject the new law.	Passed
Pending	Popular initiative "Glaciers initiative"	The organizing committee demands that the Federal Constitution is modified to include: 1) an engagement into international negotiations to limit risks and consequences of climate change, 2) carbon neutrality in Switzerland by 2050, possibly also through carbon sinks, 3) the phase out from fossil fuels by 2050, with the exception of special unavoidable uses that need however to be compensated via carbon sinks, 4) measures to foster technology innovation.	-

the liberalization wave in the retail electricity markets, the growing concern for sustainability, and the spreading of renewable-based generation.

Several studies have investigated the preferences of consumers, citizens, and investors toward renewable-based electricity supplies, while a smaller number of analyses have focussed on the acceptance of nuclear generation. These investigations have mostly relied on stated preferences, expressed through DC experiments, in contingent valuation surveys, or as an intention to purchase a given energy mix or engage in renewable generation projects. This chapter provides an overview of the main findings emerging from the surveyed literature: detailed references are provided in the text and within Table 2.

## 2.1. Preferences towards renewable energy sources

### 2.1.1. Objective of the surveyed studies

The studies concerning consumer preferences toward renewable energy sources focus either on electricity coming from renewable sources in general, or on electricity coming from a specific primary source or generation technology (Table 2). The former studies usually analyse the willingness to pay (WTP) for a higher share of renewables in the own electricity supply contract or, more generally, the diffusion of “green” energy contracts among residential consumers. The latter investigate instead whether consumers would be willing to pay different amounts of money for different renewable sources, for example within their electricity supply contract or through direct investments, or focus on the acceptance of specific renewable generation projects either in general, or among the local communities.

### 2.1.2. Estimated WTP and participation rates

Most studies detect a positive reaction of households toward a renewable-based supply.

In one of the first studies concerning the purchase of renewable-based electricity contracts, Goett et al. (2000) estimate a positive WTP among residential consumers in the USA, and detect a preference for a

mix of renewables or hydro over wind energy. Menges et al. (2005) detect a positive WTP among German households; however, they point out that WTP values might be decreasing for higher shares of renewables in the electricity supply contract. Burkhalter et al. (2009) and Plum et al. (2019) focus on Swiss households: the former detect a significant interest toward a hydro-based supply, or a supply mix including a large share of hydro plus a non-negligible share of solar, wind, and biomass energy; the latter find that solar and wind are the preferred sources to replace nuclear energy. According to both, Swiss households regard the generation mix as the most important characteristic of their supply, followed by the cost and the geographical origin of the electricity. Inland or local productions are preferred over electricity imported from abroad. Kaenzig et al. (2013) find similar results for German households: they prefer wind or a combination of wind and other renewables over any generation mix that includes fossil fuels, favour locally generated electricity and small and medium-sized electricity producers, and signal a strong interest toward labels that certify the lower environmental impact of the chosen mix. Groesche and Schroeder (2011) also find a preference for a renewable-based supply over a nuclear-based supply among German households. By including random parameters (RPs) in their regressions, moreover, they also detect a sizeable and unexplained heterogeneity in consumer preferences.

### 2.1.3. Drivers of consumer preferences: demographic variables

Going beyond the bare measurement of WTP values or enrolment rates into green energy programmes, interesting hints emerge when researchers dig into the demographic, behavioural, and attitudinal determinants of consumer preferences with respect to renewables (Table 2).

First, the surveyed literature does not provide univocal evidence regarding the role of demographic factors. Household income and a higher educational achievement are often, but not always, positively correlated to WTP. Older age and male gender tend to be negatively correlated to WTP, although some analyses report null or positive correlation. Other drivers, such as the magnitude of electricity consumption, the amount of the electricity bill, and the presence of children in the household are also mentioned, but there is no clear evidence on the direction of their impact.

### 2.1.4. Behavioural and attitudinal drivers

The investigation of behavioural and attitudinal drivers provides more stable results. The study of these drivers builds upon different streams of literature, in which economics and psychology often touch.

A first group of studies, inspired by the so-called “theory of planned behaviour” (Ajzen, 1991), connects individual actions to behavioural intentions, that are in turn determined by psychological attitudes, subjective norms, and perceived behavioural control. The link between individual attitudes and consumer preferences is confirmed by several researchers. A pro-environmental attitude, for example, is often correlated with a higher WTP for renewables or an increased acceptance of sustainable supply options, as found in Borchers et al. (2007), Oliver et al. (2011), Cicia et al., 2012, Yoo and Ready, 2014, and Bauwens, 2016. The same holds for a positive attitude towards renewable energy sources in general, as found in Nomura and Akai (2004), Hansla et al. (2008), and Litvine and Wüstenhagen (2011).

A neighbouring stream of literature focusses instead on the link between habits, behaviours, and consumer preferences. The typical example is the connection between “green behaviours”, such as waste recycling, commuting by public transport, reducing energy consumption, etc., and the decision to purchase a renewable-based supply. Amador et al. (2013) find a correlation between a higher WTP for a renewable-based supply and the regular adoption of energy saving measures. Oliver et al. (2011) measure a higher WTP for green electricity among South African households who commit to waste recycling. Whitmarsh and O'Neill (2010) argue that the regular adoption of green behaviours is the visible manifestation of a “green identity”; they find

Table 2

Studies concerning consumer preferences toward renewable energy sources.

Reference	Method	Energy sources	Object of the study	Drivers <sup>a</sup>	Geo
Goett et al. (2000)	Discrete choice experiment	Wind; hydro; mix with solar, geothermal, landfill gas	WTP for RES	-	USA
Batley et al. (2001)	Regression	RES	WTP for RES	Income (n.s.); environmental awareness (n.s.)	UK
Roe et al. (2001)	Regression	Sun and wind; hydro; coal; oil; gas; nuclear	WTP for RES; WTP for % reduction of GHG emissions per kWh	Income (+); education (+); green behaviour (+)	USA
Alvarez-Farizo and Hanley (2002)	Contingent rating; Discrete choice experiment	Wind	WTP for selected features of new wind farms	Income (+); pro-environmental attitude (+)	Spain
Zarnikau (2003)	Regression	Wind; sun	WTP for RES	Income (+); education (+); age (-)	USA
Nomura and Akai (2004)	Contingent valuation	RES; wind; sun	WTP for RES	-	Japan
Ek (2006)	Regression	Wind	Positive attitude toward wind generation	Income (n.s.); education (n.s.), age (-)	Sweden
Menges et al. (2005)	Regression	RES; wind; sun; hydro; nuclear; fossil fuels	WTP for RES	Income (+)	Germany
Bergmann et al. (2006)	Discrete choice experiment	RES	WTP for RES	Age (n.s.), children (n.s.), electricity bill (n.s.); green behaviour (n.s.)	UK
Borchers et al. (2007)	Discrete choice experiment	RES; wind; sun; biomass; farm methane	WTP for RES	Income (+); age (- for aged 31–49); pro-environmental attitude (+)	USA
Kotchen and Moore (2007)	Regression	RES	Participation in green energy programmes	Income (+); male (-); consumption (-); pro-environmental values (+); altruism/warm glow (+)	USA
Hansla et al. (2008)	Contingent valuation	RES	WTP for RES	Environmental awareness (+); attitudes toward RES (+)	Sweden
Burkhalter et al. (2009)	Discrete choice experiment	Wind; sun; hydro; nuclear	WTP for selected primary sources	-	Switzerl.
Bollino (2009)	Contingent valuation	RES	WTP for RES	Income (+); education (+); male (+)	Italy
Whitmarsh and O'Neill (2010)	Regression	Carbon offsets	Intention to purchase carbon offsets	Green behaviour (+); perceived behavioural control (n.s.); pro-environmental values (n.s.); pro-environmental self-identity (+); perceived effectiveness (n.s.); social/subjective norms (n.s.)	UK
Groesche and Schroeder (2011)	Regression	RES; nuclear	WTP for RES, WTP for nuclear	Income (+), consumption (n.s.)	Germany
Hansla (2011)	Regression	RES	WTP for RES	Altruism/warm glow (+)	Sweden
Litvine and Wüstenhagen (2011)	Regression	RES	Intention to purchase RES contract	Perceived effectiveness (+); social norms (n.s.); attitudes toward RES (+)	Switzerl.
Mewton and Cachon (2011)	Regression	RES	Elasticity of demand for green power to the own price (by electricity retailer)	-	Australia
Oliver et al. (2011)	Regression	RES	WTP for RES	Income (+); green behaviour (+)	South Africa
Cicia et al. (2012)	Discrete choice experiment	Wind; sun; biomass; nuclear	WTP for RES, WTP for nuclear	Age (-); education (+/- depending on latent class); pro-environmental behaviour (+/-); pro-environmental attitude (+); environmental awareness (+)	Italy
Strazzera et al. (2012)	Discrete choice experiment	Wind	WTA for wind generation	Latent class membership: attachment to candidate wind mill sites, consumerism, land ownership, previous experience with wind mills. Wind mill characteristics: location of the plant; public/private and regional/local property; benefits to the community; bill discount offered	Italy
Zoric and Hrovatin (2012)	Tobit; double-hurdle	RES	WTP for RES	Age (+); education (+); environmental awareness (+)	Slovenia
Amador et al. (2013)	Discrete choice experiment	RES	WTP for RES	Income (+); education (+); green behaviour (+); environmental awareness (+)	Canary Islands
Kaenzig et al. (2013)	Discrete choice experiment	RES; wind; sun; hydro	WTP for selected primary sources	-	Germany
Yoo and Ready (2014)	Discrete choice experiment	RES	WTP for RES	Energy literacy (+); pro-environmental attitude (+); environmental awareness (+)	USA
Bauwens (2016)	Correlation analysis	RES; wind; sun; hydro	Participation in green energy communities	Pro-environmental attitude (+); social norms (+); preference for local investment/producer (+)	Belgium
Conte and Jacobsen (2016)	Regression	RES	Participation in green energy programmes	Education (+); consumption (n.s.)	USA
Ma and Burton (2016)	Discrete choice experiment	RES	WTP for RES	Age (n.s.); male (-); education (n.s.)	Australia
Kim et al. (2018)	Discrete choice experiment	RES; nuclear	WTP for selected primary sources	Income (n.s.); age (n.s.); male (-); education (+); electricity bill (n.s.); altruism/warm glow (n.s.)	South Korea
Koto and Yiridoe (2019)	Contingent valuation	Wind	WTP for wind energy	Income (+); age (-); male (n.s.); education (+); house owner (-); married (-); environmental awareness (+)	Canada
Dong and Sigrin (2019)	Parametrization and calibration	Sun	WTP for PV panels	-	USA
		Sun	Investment in PV panels		Switzerl.

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Table 2 (continued)

Reference	Method	Energy sources	Object of the study	Drivers <sup>a</sup>	Geo
Petrovich et al. (2019)	Discrete choice experiment			Income (n.s.); age (n.s.); male (+); house owner (n.s.); personal savings (+); energy literacy (n.s.); pro-environmental attitude (n.s.), social norms (+); opinion on PV aesthetics (+); technical affinity (+)	

<sup>a</sup> Impact of individual drivers on the independent variable: + positive, - negative, n.s. included but not statistically significant.

that a pro-environmental self-identity is a predictor of purchases of carbon off-sets among UK residents, but point out that other determinants play a stronger role.

Energy and investment literacy, together with environmental and energy awareness, may also drive individual decisions concerning green energy supply options. The empirical evidence is however controversial. Zoric and Hrovatin, 2012 find that Slovenian households are both more likely to engage in a green energy programme, and more willing to pay for green energy if they are more aware of environmental issues. Hansla et al. (2008) also detect a significant positive correlation between the WTP for green energy and the awareness of the possible consequences of environmental problems. Whitmarsh and O'Neill (2010) find instead that the link between self-reported knowledge about climate change and pro-environmental behaviour is not significant. Similarly, Petrovich et al. (2019) in a study on Swiss households find that a sounder knowledge of the photovoltaic technology is not necessarily associated to a higher probability of investing in it.

Finally, another stream of literature depicts the purchase of renewable-based electricity as a voluntary contribution to a public good: consumer preferences are described as driven by generosity, altruism, the “warm glow” of giving, or self-transcendence. Menges et al. (2005), for example, in their experiment conducted among German households find evidence of the so-called “impure altruism”, i.e. the fact that participants gain a positive utility not only from their consumption of private and public goods, but also from personally contributing to the public good.

#### 2.1.5. Weaknesses of the surveyed literature

Although most studies elicit a positive WTP for renewable-based electricity supplies, Zoric and Hrovatin, 2012 point out that the estimates are rarely expressed with easily comparable measures, and exhibit a substantial variability. Two meta-analyses investigate whether the causes of this variability lie in the characteristics of the studies. Both Ma et al., 2015 and Sundt and Rehdanz (2015) find that the kind of renewable energy source considered in the analysis affects the WTP. Sundt and Rehdanz (2015) also highlight an effect of the primary energy source that is going to be replaced by renewables on the magnitude of the WTP. Ma et al. (2015) find moreover that some demographic variables, such as age, gender, income, electricity consumption, and education level influence the WTP estimate, but the direction of their effect is not clear-cut. Both meta-analyses highlight that the design of the study impacts the magnitude of the estimated WTP; more specifically, Sundt and Rehdanz (2015) find that DC experiments tend to produce higher WTP values than contingent valuation studies.

The link between study design and study results deserves some additional attention. The use of stated preferences analyses, largely dominant in this field, has allowed the researchers to analyse hypothetical scenarios sometimes radically departing from the status quo. This advantage has come at a price: hypothetical bias is often mentioned as a possible problem in stated preferences analyses (Foster and Burrows, 2017; McFadden, 2017), especially as the choice of an environmentally sustainable option might be subject to a social desirability bias. Zoric and Hrovatin, 2012 point out that the actual participation rates in green energy programmes are, indeed, lower than some of the estimates available in the literature. Litvine and Wüstenhagen (2011) argue however that lower participation rates in the real world might be due to the lack of effective information campaigns by energy suppliers, while

Menges et al. (2005) suggest that they might be due to consumers' inertia, i.e. a tendency to stay with the status quo contract.

#### 2.1.6. Overcoming the limitations of stated preferences

A few studies have sought to overcome the limitations of stated preferences by considering revealed preferences or other real market data. Roe et al. (2001) compare their results concerning the stated WTP of US consumers for a greener electricity supply to the price premium charged by electricity providers for their green options. Interestingly, they find that the average WTP for an additional 1% of renewable-based supply is only slightly lower than the price premium required in the green energy programmes under scrutiny. Kotchen and Moore (2007) base their analysis of voluntary contributions to public goods on survey data from US residential electricity consumers, some of which are already enrolled in the green energy programmes. Their finding that the enrolment probability increases with altruism, environmental awareness, and household income is consistent with those of comparable studies based only on stated preferences. Litvine and Wüstenhagen (2011) develop their investigation using survey data, but complement it with a follow-up analysis of the new subscriptions to a green energy programme among the electricity consumers who participated in the study. They find that providing consumers with selected information increases both the stated intention to purchase green energy, and the probability that the respondents actually subscribe to a green energy programme within four months. Bauwens, 2016 relies on a survey conducted among Belgian households participating in two community energy projects in order to investigate the motives behind the enrolment decision. He detects two - often substitute - kinds of drivers: pro-environmental orientation and identification with the local community on the one hand, financial motives on the other hand. Finally, Conte and Jacobsen, 2016 shift away from survey data, and evaluate the participation into the green energy programmes in the United States using supplier and county level data. In line with some stated preference studies, they find a positive correlation between enrolment into green energy programmes and both income and education. In sum, even if the estimated parameters are not easily comparable across studies, it seems reasonable to say that there is no glaring systematic difference between stated preferences analyses and studies based on revealed preferences or real market data.

### 2.2. Preferences toward nuclear generation

#### 2.2.1. Objectives of the surveyed studies

The preferences of citizens and households towards nuclear generation have also been investigated in the past. A nuclear option is sometimes included in the analyses of consumer preferences with respect to a renewable-based supply, especially where nuclear generation is used on a large scale, or where it is a viable alternative to renewables in order to reduce emissions (Table 2). Other studies focus instead on the WTP for nuclear generation per se (Contu et al., 2016; Contu and Mourato, 2020) or on the acceptance of nuclear generation and its drivers (Visschers et al., 2011; Stoutenborough et al., 2013; Visschers and Siegrist, 2013; Visschers and Wallquist, 2013).

#### 2.2.2. Estimated WTP for a nuclear-based supply

A review of the recent studies that examine the WTP of residential consumers for a nuclear-based supply shows that in most cases

consumers dislike nuclear generation, and rather choose renewables or, in some cases, gas-fired plants. Menges et al. (2005) find that the WTP of German households for an increased share of renewables is significantly lower if the supply contract also includes a contribution from nuclear. Kaenzig et al. (2013) estimate that German consumers would require a significant reduction in electricity prices in order to accept a 25% share of nuclear in their supply, and would prefer an equivalent contribution from gas-fired plants. Groesche and Schroeder (2011) measure a substantial decrease in German consumers' WTP if their electricity supply contract includes a higher share of nuclear. Interestingly, however, they also detect a significant heterogeneity in consumer preferences: a small, but not negligible share of respondents shows a positive WTP for nuclear generation. Kim et al. (2018) conduct a similar analysis for South-Korean households, and find that they prefer renewables over fossil fuels, and fossil fuels over nuclear. Nonetheless, the preferences towards nuclear show a sizeable heterogeneity: the authors estimate that 14.3% of respondents chose nuclear energy in the experiment, whereas only 3.3% chose fossil fuels. Looking at a country that has phased out nuclear since the late 1980s, Cicia et al., 2012 find that Italian households do not welcome nuclear energy, especially those who are more sensitive to climate change and environmental issues, and care about conducting a healthy life. There are, however, studies that detect a less negative attitude of residential consumers toward nuclear generation. According to Burkhalter et al. (2009) Swiss households prefer nuclear over fossil fuels, although they still regard both sources as less desirable than renewables. Roe et al. (2001) find that US citizens express a positive WTP for a reduction in the greenhouse gas emissions associated to electricity production, with slightly lower, but still positive values if the reduction is achieved through nuclear generation instead of renewables. Contu et al., 2016 and Contu and Mourato (2020) use DC models with latent classes to explore households' preferences with respect to fourth generation nuclear energy projects in Italy and the UK. In both cases, they find that more than 40% of the respondents are open to this technology; respondents evaluate positively both reductions in greenhouse gas emissions and nuclear waste, and compensatory measures such as land recovery, construction of new hospitals, and electricity bill discounts.

### 2.2.3. Acceptance of nuclear generation and its drivers

The studies that investigate the acceptance of nuclear generation per se shed instead a light on the role of demographic, cognitive, and emotional drivers, as well as the impact that nuclear accidents may have on acceptance.

Looking at demographic drivers, Mah et al., 2014 and Chung and Kim (2018) find that men have a better perception of nuclear than women. Sun and Zhu, 2014 and Chung and Kim (2018) also find that older respondents are less reluctant to accept nuclear generation.

Psychological drivers are considered with increasing attention. The general attitude towards nuclear generation can be influenced by the perceived risks (harmful consequences of accidents or irregular nuclear waste disposal), the perceived benefits (security of electricity supply, lower greenhouse gas emissions, reduced need of fuel imports, lower electricity bills), trust in the government or institutions in charge of overseeing nuclear generation, energy literacy especially in the field of nuclear generation, and finally environmental concerns. According to some researchers, political views may also play a role. These drivers are often intertwined: energy literacy, for example, is often connected to risk perception. More in detail, Visschers et al. (2011), Stoutenborough et al. (2013), and Visschers and Siegrist (2013) find that a lower perception of the risks associated to nuclear generation, a higher perception of its benefits, and a stronger trust in the institutions in charge of overseeing nuclear plants are positively correlated to a higher acceptance of this technology. Visschers and Siegrist (2013) report on the results of a longitudinal survey conducted in Switzerland before and after the Fukushima accident. Despite measuring a lower public support for nuclear generation after the accident, they argue that the

relationships between risk and benefit perceptions and trust on the one hand, and acceptance of nuclear on the other hand, have not been affected by the accident. Contu et al., 2016 confirm that the acceptance of nuclear energy is negatively correlated to the perceived risks, and positively correlated to perceived benefits and confidence in the achievement of the fourth generation reactors' goals. Moreover, they highlight that risk perception is positively correlated to egoistic values, and benefit perception to altruistic ones. Contu et al., 2016 and Contu and Mourato (2020) also exploit psychological drivers within their DC models and find that a higher confidence in fourth generation reactors, a lower perception of the associated risks and a higher perception of the associated benefits are correlated to a higher likelihood of belonging to the latent class of moderate nuclear supporters.

The individual literacy about nuclear generation and energy issues in general also impacts the acceptance of this technology. Jun et al. (2010) find that South-Korean survey participants who received accurate information about nuclear generation expressed a higher WTP for a nuclear-based supply. Stoutenborough et al. (2013) detect a positive, although limited impact of a better knowledge of energy and nuclear issues on the US citizens' support for nuclear energy. Stoutenborough and Vedlitz, 2016 point out that self-reported knowledge often differs from actual knowledge; a higher self-reported knowledge of nuclear generation is often associated to a higher risk perception, whereas the reverse holds for actual knowledge. Thus, they recommend a cautious approach when deciding about the way in which knowledge about nuclear energy is included in the analysis. Finally, Contu et al., 2016 find that individuals who have heard about fourth generation reactors are more likely to be moderate nuclear supporters, and Contu and Mourato (2020) detect a positive correlation between having heard of fourth generation reactors and the WTP for research programmes concerning this technology.

### 2.3. Our contribution to the literature

Our analysis investigates the preferences of Swiss households with respect to selected renewable energy sources, nuclear generation, and a variable share of renewable energy from unspecified sources within a "grey mix" contract. In line with comparable studies (Table 2), we evaluate households' preferences for each primary energy source, and assess the impact of demographic, behavioural, and attitudinal drivers on households' choices.

The use of a DC model allows us to study the different dimensions of the electricity supply contract that may matter to the consumer: price, primary energy source used, and supply reliability. This approach has already been adopted in previous studies evaluating households' preferences for different characteristics of the own electricity contract (Goett et al., 2000; Burkhalter et al., 2009; Amador et al., 2013; Kim et al., 2018). The structure of our DC model allows us to investigate whether households' preferences for different energy sources also depend on their reliability, and shed light on a topic that has rarely been considered in the vast literature concerning the acceptance of specific primary energy sources and generation technologies (among the exceptions: Amador et al., 2013; Cohen et al., 2016; Kim et al., 2018; Merk et al., 2019; Siyaranamual et al., 2020).

In line with several studies mentioned in Table 2 and subsection 2.2, we investigate and quantify the possible impact of demographic and behavioural variables on consumer preferences for specific energy sources. Moreover, by including LVs representing attitudes directly into the HDCM, we also study the possible role of psychological traits, such as environmental awareness, trust in the traditional generation technologies, and other latent drivers that have been considered in the existing literature (Table 2). The structural equations describing each LV in our HDCM allow us to connect each attitude to a set of relevant demographic and behavioural variables, and thus provide a more nuanced representation of individual behaviour as compared to the studies where psychometric indicators are directly included in the DC model (Borchers

et al., 2007; Petrovich et al., 2019). By accounting for attitudinal traits, we are able to improve the efficiency of our estimates and provide a better understanding of the drivers of consumer behaviour. Our results may provide useful insights to policy makers involved in the energy transition and electricity retailers facing the challenges of decarbonisation and possible market opening.

### 3. Methodology

As already mentioned, the method we chose is a HDCM.

DC analysis assumes that a decision maker, when facing a set of mutually exclusive and collectively exhaustive alternatives, selects the one that provides him/her with the highest indirect utility. The utility the decision maker extracts from each alternative depends on the alternative's characteristics, the so-called "attributes", and may be influenced by the decision maker's demographic characteristics and attitudinal traits (Ben-Akiva and Lerman, 1985).

We expand the basic multinomial logit (MNL) specification of DC models by explicitly including attitudes as LVs in the observable component of the utility functions (Walker, 2001; Bolduc and Alvarez-Daziano, 2010; Abou-Zeid and Ben-Akiva, 2014). We estimate each LV simultaneously within the HDCM, and exploit as indicators the psychometric data, visible manifestations of the underlying latent attitude. Thus, we avoid the measurement error implicit in any fitted attitudinal variable developed ex ante using selected psychometric indicators (Train et al., 1987).

The econometric specification of a HDCM with LVs consists of the following equations (Walker, 2001; Abou-Zeid and Ben-Akiva, 2014)<sup>1</sup>:

$$U_{ijt} = V_{ij}(Z_{jt}, X_i, X_i^*; \beta) + \varepsilon_{ijt}, \text{ with } \varepsilon_{ijt} \text{ i.i.d. } \sim EV(0, \mu_\varepsilon) \quad [1]$$

$$y_{ijt} = 1 \text{ if } U_{ijt} = \max_k \{U_{ikt}\}, \quad y_{ijt} = 0 \text{ otherwise} \quad [2]$$

$$X_i^* = h(X_i; \lambda) + \omega_i, \quad \omega_i \sim N(0, \Sigma_\omega) \quad [3]$$

$$I_i = m(X_i, X_i^*; \alpha) + v_i, \quad v_i \sim N(0, \Sigma_v) \quad [4]$$

Where:

- $U_{ijt}$  is the utility that respondent  $i$  extracts from choosing alternative  $j$  in choice task  $t$ ,
- $Z_{jt}$  is a vector of attributes of alternative  $j$  in choice task  $t$ ,
- $X_i$  is a vector of respondent  $i$ 's demographic variables,
- $X_i^*$  is a vector of respondent  $i$ 's unobservable LVs,
- $I_i$  is a vector corresponding to respondent  $i$ 's answers in selected psychometric statements,
- $\beta$ ,  $\lambda$ , and  $\alpha$  are vectors of parameters to be estimated.

The HDCM is estimated via simulated maximum likelihood. The likelihood function corresponds to the integral of the DC model over the distribution of the LVs, as measured through the selected indicators:

$$L = \int P(y_{ijt}|Z_{jt}, X_i, X_i^*; \beta, \Sigma_\varepsilon) * g(I_i|X_i, X_i^*; \alpha, \Sigma_v) * f(X_i^*|X_i; \lambda, \Sigma_\omega) dX_i^* \quad [5]$$

This mathematical framework allows the researchers to explore the systematic, but otherwise unobservable drivers of heterogeneity in consumer behaviour, and quantify the magnitude of their impact on consumer choices (Vij and Walker, 2016). As the estimation process is rather complex (Abou-Zeid and Ben-Akiva, 2014), some researchers (Mariel and Meyerhoff, 2016) have raised concerns regarding the performance of these models with respect to RP DC models that exploit simpler estimation procedures to measure heterogeneity without

investigating its drivers. Mariel and Meyerhoff, 2016 argue however that while the predictive power of the two types of models is comparable, HDCM with LVs provide insights into the "black box" of the choice process that cannot be obtained through an ex post analysis of the distributions of RPs. Moreover, HDCM with LVs outperform RP models when the assessment of the magnitude and direction of the impact of psychological drivers on consumer choices is relevant to policy making (Mariel and Meyerhoff, 2016; Vij and Walker, 2016). Finally, Vij and Walker, 2016 argue that HDCM with LVs improve on specifications neglecting latent constructs whenever the researchers need to test more sophisticated hypotheses on consumer behaviour, and help identifying observable variables that impact choices through latent constructs, thus reducing the risk of incurring into omitted variable bias.

Some researchers (Abou-Zeid and Ben-Akiva, 2014; Chorus and Kroesen 2014) have discussed the limitations of HDCMs with LVs from a practical perspective, questioning the possibility of drawing policy suggestions based on this kind of models. They argue that latent attitudes may be endogenous to individual choices, particularly in revealed preference analyses, and that policy recommendations should not target LVs, as these are usually collected at one point in time, and thus their impact on choices can only be evaluated through between-person comparisons. Within our setting, however, these concerns should not hinder the development of sound policy implications. First, the possible endogeneity of the LVs is less problematic, as our DC analysis is based on stated preferences and thus a reverse effect from choices to LVs is less likely to happen (Abou-Zeid and Ben-Akiva, 2014; Chorus and Kroesen 2014; Vij and Walker 2016). Secondly, the fact that we describe LVs through structural equations exploiting observable demographic and behavioural variables implies that we are able to provide a better representation of the channels through which these observable variables influence consumer preferences, and to evaluate what consequences may derive from policies or exogenous changes impacting specific observable variables rather than LVs per se (Vij and Walker 2016). On the other hand, our insight into the attitudinal drivers of household choices may serve as a basis to evaluate scenarios in which these drivers should change for exogenous reasons. Finally, a detailed understanding of the way individuals decide may support the design of communication or information strategies eliciting the desired reactions among citizens (Vij and Walker 2016).

### 4. Data

We conducted the DC experiment by means of an on-line survey, that was translated in French and German and distributed in January and February 2015 through an independent market research company. We collected 1006 valid responses, including a pre-test on a sub-sample of approximately 100 respondents. The sample was stratified in order to ensure a reasonable representativeness of the Swiss population. Descriptive statistics are available in Appendix B.

#### 4.1. Structure of the survey

The survey included:

- A short introduction explaining the purpose of the analysis,
- 30 psychometric questions: the respondents were asked to state on a 7-points Likert scale their agreement or disagreement with statements concerning electricity production and consumption and environmental problems. The statements were developed drawing from the surveyed literature,
- Questions regarding the respondent's habits and behaviour in the fields of energy consumption and environmental sustainability,
- Questions regarding the typical demographic variables,
- The DC experiment, consisting in seven choice tasks: in each of them, the respondents had to choose one out of five alternative electricity supply contracts for their own dwelling (Table 3). A short

<sup>1</sup> Further details on the functioning of HDCMs with LVs are provided in Appendix A.

**Table 3**

Example of a choice task.

Please select the electricity supply contract you would be ready to sign for your own flat or house. You can choose only one contract.					
	Nuclear	Mix - of which 60% from renewables	Hydro	Solar	Wind
Price (centCHF/kWh)	18	27.5	21	24	50
Nr of 5 min blackouts	0	1 per year	1 per year	4 per year	1 per year
Nr of 4 h blackouts	4 per year	4 per year	0	0	0
Your choice:					

introductory text described the contributions of each primary energy source, the average electricity price, and the average blackout frequency and duration observed in Switzerland during the previous year.

#### 4.2. Structure of the DC experiment

The alternative contracts included in each choice task were described through the following attributes:

- Kind of primary energy source used, also used as a label to identify the alternatives. In order to reduce complexity for the layman, the DC experiment did not mention specific generation technologies,
- Price of electricity in centCHF/kWh
- Frequency of short (5 min) blackouts,
- Frequency of long (4 h) blackouts,
- Share of renewable-based generation from unspecified energy sources in the “mix” alternative.

Table 4 provides an overview of the attributes and corresponding levels. Some price levels were not available for all alternatives, and the attribute “share of electricity from renewable energy sources” was only available for the mix alternative. The attribute levels were defined based on the current and prospective structure of the electricity generation and retailing activities in Switzerland (BFE - Bundesamt für Energie, 2018), and drawing from the experiences of other European countries.

The blackout attributes were described to the respondents as most likely frequencies of a short or long interruption over the upcoming years. When opting for a specific contract, the respondent did not commit to an interruptible service, but rather accepted a given outage risk.

#### 4.3. Design of the DC experiment

The choice tasks were developed using the software NGene through

**Table 4**

DC experiment: alternatives, attributes, and attribute levels.

Attributes	Levels
Primary energy source used for generation (This attribute is used as a label for the alternatives included in each choice task)	nuclear; mix; hydro; sun; wind
Price (cent CHF/kWh)	14.5 (not available for hydro, sun, wind); 18 (not available for sun); 21; 24; 27.5; 50
Nr of 5 min blackouts	0; 1 every four years; 1 per year; 4 per year
Nr of 4 h blackouts	0; 1 every four years; 1 per year; 4 per year
% of electricity from renewable sources (This attribute is defined only for the mix alternative)	40; 60; 80; 100

an efficient design with blocking.

The priors for the attributes’ parameters were defined based on the surveyed literature: we assumed a slight preference for renewables over the nuclear and mix alternatives, a modest dislike for price increases, and a stronger aversion for short and long blackouts. We also expected a sizeable heterogeneity in consumer preferences with respect to nuclear generation, and a non-zero covariance in the error terms of the nuclear and hydro alternatives, building the backbone of the Swiss electric system, and in those of the 100% renewable based alternatives, namely hydro, sun, and wind. Thus, we defined the optimal choice task structure by averaging a RP and an error component specification.

The final design consisted in eight blocks containing seven choice tasks each: each respondent was randomly assigned to one of the eight blocks. Thus, we collected 7042 choices.

## 5. Results

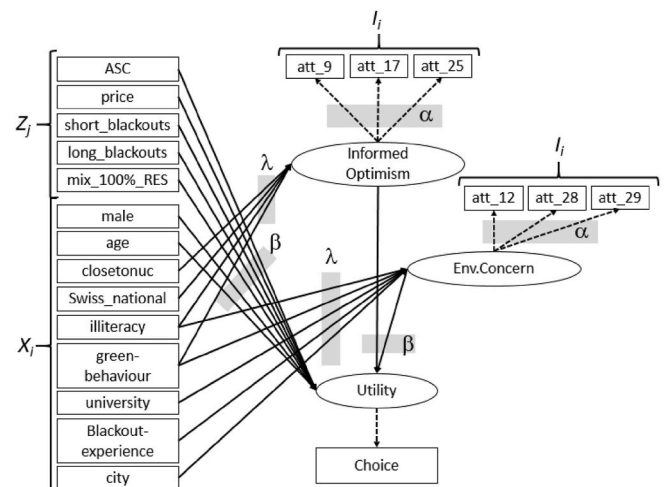
### 5.1. Overview

Using the software PythonBiogeme (Bierlaire, 2016) we estimated a series of DC models with increasing complexity. Considering the model fit (McFadden adjusted R-squared), significance of the results, and coherence with comparable studies, we chose a HDCM with two LVs as our preferred specification.

Fig. 1 provides a visual description of our HDCM according to the standard format described in Walker (2001) and Abou-Zeid and Ben-Akiva, 2014. Consumer preferences are directly influenced by the alternatives’ attributes ( $Z_j$ ), a set of observable demographic and behavioural characteristics of the respondents ( $X_i$ ), and two attitudes characterizing the same respondents, the LVs “informed optimism” and “environmental concern” ( $X_i^*$ ). Each LV is identified through the responses provided to three psychometric indicators ( $I_i$ ), and is in turn correlated to a set of observable demographic and behavioural variables. Rectangles represent observable variables, ovals latent constructs; solid arrows correspond to structural equations, dotted arrows to measurement equations.

The two LVs representing attitudinal traits of the respondents were identified starting from a principal component analysis of the responses collected in the attitudinal statements’ section of the survey. Table 5 provides an overview of the two main components that were tested and exploited to build the LVs.

Components 1 and 2 are related to the kind of energy source used for generating electricity, and show reasonably good properties in terms of explained variance and internal consistency, as measured by the Cronbach Alpha. Component 1 measures a positive attitude towards

**Fig. 1.** Scheme of the HDCM with two LVs.



**Table 5**

Results of a principal component analysis of the responses provided to the attitudinal statements.

	Average	Standard Deviation	Loading	% of variance	Cronbach Alpha
<b>The statements are evaluated on a Likert scale from 1 to 7, where 1 means "Completely disagree", 7 means "Completely agree"</b>					
<b>Component 1: "Environmental concern"</b>					
att_29: I am worried about climate change	5.52	1.50	0.30	20.8%	0.76
att_12: I am worried about pollution	5.84	1.30	0.30		
att_28: It is important to generate electricity using renewable energy sources	6.36	1.04	0.29		
<b>Component 2: "Informed optimism"</b>					
att_9: I think the risk of a nuclear accident in Switzerland is very low	4.22	1.84	0.32	6.7%	0.69
att_25: It is dangerous to live close to a nuclear generation plant	4.60	1.92	-0.40		
att_17: It is dangerous to live close to a gas-fired generation plant	3.88	1.60	-0.42		

environmental issues: hence, we named the corresponding LV "environmental concern". Component 2 measures instead a confident attitude towards the risk of accidents involving nuclear generation and gas-fuelled plants; we defined the corresponding LV as "informed optimism".

Table 6 collects the detailed results of our estimations: the HDCM with two LVs depicted in Fig. 1 is identified as model [4]. As a term of comparison, Table 6 also collects the results of two MNL specifications, models [1] and [2], and a RP specification, model [3].

## 5.2. Main findings

The results collected in Table 6 allow us to draw three main messages concerning the preferences of Swiss households toward the energy sources considered in the analysis.

First, household preferences are expressed as different sensitivities toward variations in the price and reliability of the electricity supply depending on the source used, rather than as *ceteris paribus* preferences for each source per se. Table 6 shows indeed that the alternative-specific constants ( $ASC_{source}$ ), that measure preferences for each primary energy source per se, are not statistically significant, with the exception of the wind-based contract. The price and blackout coefficients ( $Beta_{price\_source}$ ,  $Beta_{short\_blackout\_source}$ ,  $Beta_{long\_blackout\_source}$ ) are instead negative, as expected, and show that price sensitivity hits its maximum for the nuclear contract, blackout sensitivity for the wind-based supply.

Secondly, among the typical demographic variables only gender and age are directly correlated to a higher propensity to choose a specific primary energy source. Men are more likely than women to choose the nuclear or hydroelectric options ( $Beta_{male\_nuc}$ ,  $Beta_{male\_hydro}$ ) and less likely to choose the solar one ( $Beta_{male\_sun}$ ); older respondents are more likely to go for the mix alternative ( $Beta_{age\_mix}$ ). Other demographic and behavioural variables influence consumer preferences only indirectly, through their correlation with the two LVs.

Finally, individual attitudes as measured by the two LVs do influence consumer choices. A higher value of the LV environmental concern is associated to a more positive evaluation of a 100% renewable-based supply in the mix alternative ( $Beta_{LV\_Env.Concern\_mix\_100\%\_RES}$ ). A higher value of the LV informed optimism is instead associated to a higher propensity to choose the nuclear option ( $Beta_{LV\_InformedOptimism\_nuc}$ ). The structural equations connecting each LV to the relevant demographic and behavioural drivers reveal that environmental concern is positively correlated to the regular adoption of green behaviours (variable "green behaviour"), having a university degree, living in a city rather than in a town or in the countryside, being less informed about the own energy consumption pattern ("illiteracy"), and finally having experienced one or more blackouts in the past 12 months. The LV informed optimism is instead negatively correlated to green behaviour, illiteracy, residing in a district close to a nuclear generation plant, and finally being a Swiss national. The magnitude of the impact of the LVs is comparable to that of gender.

It is interesting to note that environmental concern does not influence consumer preferences towards the sun-, hydro-, or wind-based contracts ( $Beta_{LV\_Env.Concern\_RES}$ ), nor towards the mix alternative per se ( $Beta_{LV\_Env.Concern\_mix}$ ). Instead of choosing a specific energy source, the environmentally concerned respondents rather leave to their supplier the choice of the renewable energy mix. On the other hand, the dummy variable for a 100% renewable-based supply in the mix alternative ( $Beta_{mix\_100\%\_RES}$ ) does not produce a significant coefficient per se: the interest in a renewable-based supply is only kindled among the consumers that record a higher environmental sensitivity.

It is also interesting to remark that the estimates are stable across the four specifications, with just two exceptions. Indeed,  $Beta_{mix\_100\%\_RES}$  is positive in models [1] and [2], positive, but with a sizeable standard deviation ( $Beta_{mix\_100\%\_RES\_stddev}$ ) in model [3], and not significant in model [4]. This suggests that the MNL specifications hide some substantial heterogeneity, and that the inclusion of the LV environmental concern ( $Beta_{LV\_Env.Concern\_mix\_100\%\_RES}$ ) is crucial to improve the assessment and understanding of consumer preferences toward renewables. Similarly, model [3] detects a sizeable heterogeneity in *ceteris paribus* attitudes towards the nuclear alternative ( $ASC_{nuclear\_stddev}$ ), which is explained in model [4] through the LV informed optimism ( $Beta_{LV\_InformedOptimism\_nuc}$ ).

## 5.3. Attitudinal and behavioural drivers: discussion

The findings concerning the link between green behaviour and illiteracy on the one hand, and the environmental concern and informed optimism on the other hand, deserve some additional comment.

The variable green behaviour is an index ranging from 0 to 3; the respondent gets one point for having a renewable-based contract, one for always switching off lights when not needed, and one for lowering the heating at night. The structural model for environmental concern suggests that the strongest observable predictor of this latent construct is the regular adoption of environmental-friendly choices in everyday life. This finding is coherent with the suggestions of the literature concerning the link between the propensity to choose a renewable-based supply on the one hand, and green habits, behaviour, or identity on the other hand (Whitmarsh and O'Neill, 2010; Oliver et al., 2011; Amador et al., 2013).

The variable illiteracy is instead an index ranging from 0 to 7 and counting how many times the respondents answered "I don't know" in a series of questions regarding the average electricity bill and the availability of green facilities at the own dwelling.<sup>2</sup> The structural model for environmental concern reveals that energy illiteracy is positively correlated to the pro-environmental attitude: this suggests that the environmentally concerned respondents might be attracted by the warm glow feeling sparked by the choice of a green option, rather than by the

<sup>2</sup> The facilities included in the list are: insulating windows, insulating wall panels, solar heating, photovoltaic panels, other Minergie equipment, other energy saving devices, other devices for exploiting renewable energy.

**Table 6**  
Estimated parameters.

	[1] MNL	[2] MNL with demographic variables	[3] RP with demographic variables	[4] HDCM with LVs
Nr of estimated parameters	22	31	33	54
McFadden adj. R squared	0.22	0.23	0.23	0.36
Nr. of Halton draws	-	-	500	500
Nr. of individuals	1006	1006	1006	1006
<b>Parameters: discrete choice model</b>				
ASC_hydro	0.106	0.572*	0.581**	0.273
ASC_nuclear	-1.01***	-0.0683	-1.01* 2.42***	-0.283
ASC_sun	-0.0769	0.672**	0.696***	0.379
ASC_wind	0.683***	1.24***	1.25***	0.941***
Beta_price_hydro	-0.0571***	-0.0573***	-0.058***	-0.0573***
Beta_price_mix	-0.0615***	-0.062***	-0.067***	-0.062***
Beta_price_nuc	-0.0884***	-0.0927***	-0.112***	-0.0916***
Beta_price_sun	-0.0477***	-0.0481***	-0.049***	-0.0481***
Beta_price_wind	-0.0801***	-0.0801***	-0.0805***	-0.0802***
Beta_mix_100%_RES	0.556***	0.559***	0.538*** 1.26***	-0.0681
Beta_mix_40%_RES	-0.0266	-0.0249	0.0211	-0.0235
Beta_mix_80%_RES	0.0818	0.0836	0.107	0.081
Beta_short_blackout_hydro	-0.128***	-0.128***	-0.131***	-0.129***
Beta_short_blackout_mix	-0.0642***	-0.0665***	-0.0676***	-0.0664***
Beta_short_blackout_nuc	-0.138***	-0.145***	-0.176***	-0.145***
Beta_short_blackout_sun	-0.137***	-0.139***	-0.145***	-0.139***
Beta_short_blackout_wind	-0.215***	-0.216***	-0.222***	-0.215***
Beta_long_blackout_hydro	-0.445***	-0.448***	-0.456***	-0.447***
Beta_long_blackout_mix	-0.283***	-0.285***	-0.304***	-0.286***
Beta_long_blackout_nuc	-0.269***	-0.284***	-0.359***	-0.281***
Beta_long_blackout_sun	-0.432***	-0.436***	-0.444***	-0.436***
Beta_long_blackout_wind	-0.564***	-0.566***	-0.579***	-0.566***
Beta_age_mix		0.0147***	0.0172***	0.0149***
Beta_male_hydro		0.249*	0.252**	0.25*
Beta_male_nuc		0.756***	1.2***	0.731***
Beta_male_sun		-0.33**	-0.336***	-0.33**
Beta_male_wind		0.065	0.0673	0.067
Beta_green-behaviour_nuc		-0.445***	-0.769***	
Beta_blackout-experience_nuc		0.289***	0.418***	
Beta_illiteracy_nuc		-0.0603	-0.0541	
Beta_Swiss_nuc		-0.00209***	-0.00394***	
Beta_LV_Env.Concern_RES				-0.273
Beta_LV_Env.Concern_mix_100%_RES				0.123***
Beta_LV_Env.Concern_mix				-0.333
Beta_LV_InformedOptimism_nuc				0.633*
<b>Parameters: LV "Environmental concern"</b>				
Lambda_LV_Env.Concern_city				0.633***
Lambda_LV_Env.Concern_green-behaviour (lights, heating, RES)				1.78***
Lambda_LV_Env.Concern_blackout-experience (at least 1)				0.286**
Lambda_LV_Env.Concern_illiteracy (insulating windows/walls, solar heating, PV, minergie, el. bill, other en. sav. eq., other RES eq.)				0.532***
Lambda_LV_Env.Concern_university				0.986***
Alpha_LV_Env.Concern_att12 (I am worried about pollution)				0.164***
Alpha_LV_Env.Concern_att28 (Generating electricity via RES is important)				0.0879***
Psychometric indicators: intercepts and sigmas				✓
<b>Parameters: LV "Informed optimism"</b>				
Lambda_LV_InformedOptimism_Swiss_national				-0.00203***
Lambda_LV_InformedOptimism_closetonuc (resides in a district with nuclear or bordering a French/Swiss district with nuclear)				-0.469***
Lambda_LV_InformedOptimism_green-behaviour (lights, heating, RES)				-1.43***
Lambda_LV_InformedOptimism_illiteracy (insulating windows/walls, solar heating, PV, minergie, electricity bill, other en. sav. eq., other RES eq.)				-0.48***
Alpha_LV_InformedOptimism_att25 (It is dangerous to live close to a nuclear generation plant)				-0.184***
Alpha_LV_InformedOptimism_att9 (I think the risk of a nuclear accident in Switzerland is very low)				0.181***
Psychometric indicators: intercepts and sigmas				✓

\* Significant at 5%; \*\* Significant at 1%, \*\*\* Significant at 0.1%.

actual environmental impact of their chosen option. This finding is particularly interesting if we consider it against the literature concerning the role of green labels, such as the EU Energy Labels, in influencing consumer choices. [Andor et al. \(2020\)](#) show, for the neighbouring sector of energy efficiency of household appliances, that consumers use heuristic thinking and rely on energy efficiency labels for their choices rather than investigating the real energy (and economic) savings achieved by the chosen product or service. It is crucial, then, that energy labels are carefully designed and closely monitored, in order to ensure that they meet a given environmental standard and fulfil the customers' expectation of a lower environmental impact. According to our estimates, this message also holds for the labels used for energy supply contracts.

The structural model for the LV informed optimism suggest instead that the respondents showing a more positive attitude towards nuclear generation and fossil fuels are, less likely to adopt green behaviours, but also better informed as regards their own energy consumption patterns. It is plausible to assume that a more accurate knowledge of the own consumption is a signal of a stronger interest in energy-related issues and, possibly, an increased awareness of the risks and benefits of the available generation technologies. If this is the case, our result confirms the findings of [Jun et al. \(2010\)](#), and [Stoutenborough et al. \(2013\)](#) as regards the role of knowledge and information in favouring the acceptance of the nuclear technology. It is also interesting to note that the respondents who show a high level of informed optimism - and are hence more likely to accept a nuclear-based supply - are less likely to live close to a nuclear plant. The demographic variable "close to nuclear" is a 0–1 dummy that takes value 1 if the respondent lives in a Swiss district that hosts a nuclear plant, or borders a district hosting a nuclear plant, or borders France in close proximity to a French nuclear plant.

## 6. Conclusion and policy implications

Decarbonizing the economy is one of the biggest challenges that modern economies face in this decade. Switzerland, as several other countries, has drafted a long-term strategy to achieve its decarbonisation target and phase out nuclear generation. The acceptance of citizens is a key ingredient for a smooth and efficient evolution of the energy systems, particularly where citizens are entitled to contribute to the definition of energy policies through referenda.

We build on the suggestions of the literature concerning household preferences for renewable energy sources and acceptance of nuclear energy, and develop an original contribution in which latent attitudinal drivers are explicitly considered among the determinants of individual behaviour towards each primary energy source. Our model sheds light on the multidimensional nature of consumer preferences by measuring households' reactions toward changes in the origin, price, and reliability of the own electricity supply, quantifies the influence of demographic, behavioural, and attitudinal drivers on household choices, and finally evaluates the relation between attitudes and demographic and behavioural variables.

We find that household preferences toward different primary energy sources translate into different sensitivities toward variations in the price and reliability of the own electricity supply. Our measures of the trade-offs that consumer perceive among these attributes may help electricity retailers in defining the combinations of prices and energy sources that best meet their customers' expectations, and provide a basis for exploring the potential for demand response among residential consumers. Moreover, our assessment of the perceived trade-offs between the sustainability, affordability, and security of electricity supply may support the design of a transition path that elicits the least opposition among citizens.

Our analysis also points out that a few characteristics of the individuals, among which the attitudinal drivers environmental concern and informed optimism, directly influence consumer preferences. A higher environmental concern is associated to a stronger preference for a

100% renewable-based mix, whereas a higher informed optimism is associated to an increased likelihood of accepting a nuclear-based supply. While it is difficult to envisage policies specifically targeting the above-mentioned attitudinal drivers, our findings suggest that policy makers or other stakeholders might target instead individual behaviours that show a significant correlation with them. Information campaigns or policies promoting the regular adoption of environmental-friendly behaviours could foster environmental sensitivity, while initiatives aimed at spreading a higher awareness of the own energy consumption patterns could improve informed optimism. Moreover, policy makers or electricity companies might consider monitoring the evolution of the relevant attitudes through standing panels, repeated surveys,<sup>3</sup> or other research approaches.

Our results also show that a higher environmental concern – and hence a higher probability of choosing a 100% renewable-based supply from unspecified sources – tends to be associated to a lower energy literacy. As residential consumers may naively choose renewable-based supply options for altruistic reasons or environmental sensitivity, policy makers and energy regulators should carefully monitor the formal and informal labelling of electricity supply contracts by retailers, and ensure that options marketed as "green" actually meet the expectations of their subscribers.

This study is also subject to some limitations that can serve as a starting point for further research.

In the first place, our analysis is based on Swiss data. Hence, while our results concerning the increasing importance of attitudinal drivers in determining consumer preferences towards the energy transition are probably valid for most countries, the role of specific attitudes and the shape of consumer preferences could change depending on the context. Replicating the analysis in other countries with a different generation mix and different procedures for achieving or acknowledging citizens' consensus might yield interesting insights into the relationship between context, attitudes, and preferences.

Secondly, we recognize that the role of specific attitudinal drivers might change along with the implementation of the energy transition. A careful evaluation of the evolution of consumers' attitudes and preferences could inform strategies to elicit or preserve consensus while progressing in the restructuring of the energy system.

Finally, we do not address consumer preferences with respect to the distributed generation technologies that provide an alternative to the purchase of a green contract from the traditional electricity suppliers. Several contributions have assessed consumer preferences toward specific features of the new small-scale generation technologies ([Alvarez-Farizo and Hanley, 2002](#); [Petrovich et al., 2019](#)), explored the drivers of households' investment decisions ([Petrovich et al., 2019](#)), or evaluated the motives behind the decision of joining a local energy community ([Bauwens, 2016](#)). An investigation into the subjective and objective drivers that influence the choice between purchasing a green contract, investing in a private generation system, or joining an energy community might bridge the gap between these neighbouring streams of research.

## Credit author statement

Within the project funded through the Swiss National Science Foundation Grant CR1211\_140740, Alessandra Motz has carried out the entire work described in this submission, under the supervision of Prof. Rico Maggi.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

<sup>3</sup> An example in Switzerland is [Cousse et al. \(2020\)](#).

the work reported in this paper.

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## Appendix A

This Appendix provides further details on the mathematical structure of a HDCM with LVs. We refer to [Ben-Akiva and Lerman \(1985\)](#) for further details on the functioning of DC models, and [Walker \(2001\)](#) and [Abou-Zeid and Ben-Akiva, 2014](#) for an insight on the structure, advantages, and limitations of HDCM with LVs.

The basic structure of a DC model is the following:

$$U_{ijt} = V_{ij}(Z_{jt}, X_i; \beta) + \varepsilon_{ijt}, \text{ with } \varepsilon_{ijt} \text{ i.i.d. } \sim EV(0, \mu_\varepsilon) \quad [6]$$

$$y_{ijt} = 1 \text{ if } U_{ijt} = \max_k \{U_{ikt}\}, \quad y_{ijt} = 0 \text{ otherwise} \quad [7]$$

Where  $U_{ijt}$  is the utility that respondent  $i$  extracts from choosing alternative  $j$  in choice task  $t$ ,  $Z_{jt}$  is a vector of attributes of alternative  $j$  in choice task  $t$ ,  $X_i$  is a vector of respondent  $i$ 's demographic variables,  $\beta$  is a vector of parameters to be estimated, and  $y_{ijt}$  is a dichotomous variable that takes value 1 if respondent  $i$  chose alternative  $j$  in choice task  $t$ , and 0 otherwise. In other words, the DC model assumes that:

- In choice task  $t$  respondent  $i$  will choose alternative  $j$  within the choice set  $C_t$  if  $j$  is the alternative that provides him/her the highest utility:  $P(y_{ijt}) = P(U_{ijt} \geq U_{ikt}, \forall j \in C_t)$
- The utility that  $i$  draws from each alternative  $j$  can be described as the sum of a deterministic and a random component. The former depends on the alternatives' characteristics  $Z_j$  and on  $i$ 's demographic variables  $X_i$ , the latter is modelled as an error term that, in the case of the MNL model, is assumed to be i. i. d.  $\sim EV(0, \mu_\varepsilon)$ .

The basic DC model thus consists of:

- A structural equation [A.1], connecting the inherently unobservable utility of respondent  $i$  to  $i$ 's observable characteristics and to the observable characteristics of each alternative  $j \in C_t$
- A measurement equation, [A.2], connecting  $i$ 's unobservable utility to an observable indicator choice indicator,  $y_{ijt}$ , i.e. respondent  $i$ 's choice in choice task  $t$ .

In the case of a HDCM with LVs, this basic framework is expanded to include in the deterministic component of the utility function one or more LVs  $X_i^*$ , each representing an attitudinal trait of the respondent that may influence his/her choices. Equation [A.1] thus becomes:

$$U_{ijt} = V_{ij}(Z_{jt}, X_i, X_i^*; \beta) + \varepsilon_{ijt}, \text{ with } \varepsilon_{ijt} \text{ i.i.d. } \sim EV(0, \mu_\varepsilon) \quad [8]$$

The attitudinal traits of the respondent are included in the form of LVs because they cannot be directly observed as such, but are rather revealed by the respondent through his/her evaluations of a set of psychometric indicators. Thus, each LV  $X_i^*$  describing an attitudinal trait is modelled through a structural equation, [A.4], connecting the LV to the relevant observable demographic variables, and a few measurement equations [A.5], connecting the LV to a set of relevant psychometric indicators  $I_i$ :

$$X_i^* = h(X_i; \lambda) + \omega_i, \omega_i \sim N(0, \Sigma_\omega) \quad [9]$$

$$I_i = m(X_i, X_i^*; \alpha) + v_i, \quad v_i \sim N(0, \Sigma_v) \quad [10]$$

Where  $\lambda$  and  $\alpha$  are parameters to be estimated.

Assuming that the error terms  $\varepsilon$ ,  $\omega$  and  $v$  are independent, the joint probability that respondent  $i$  chooses alternative  $j$  in choice task  $t$  and provides a given evaluation for indicator  $I_i$  is:

$$P(y_{ijt}, I_i | Z_{jt}, X_i^*, X_i; \beta, \alpha, \lambda; \Sigma_\varepsilon, \Sigma_v, \Sigma_\omega) = \int P(y_{ijt} | Z_{jt}, X_i^*, X_i; \beta, \Sigma_\varepsilon) * g(I_i | X_i, X_i^*; \alpha, \Sigma_v) * f(X_i^* | X_i; \lambda, \Sigma_\omega) dX_i^* \quad [11]$$

That is, the probability that respondent  $i$  chooses alternative  $j$  in choice task  $t$  conditional on the distribution of each LV  $X_i^*$ , multiplied by the conditional density function of the indicators, integrated over the density function of the LV  $X_i^*$ .

Based on this framework, HDCMs with LVs can be estimated via simulated maximum likelihood, using an appropriate software as explained in chapter 3.



## Appendix B

Table B.1

Descriptive statistics for the sample and the Swiss population<sup>a</sup>

Gender	Sample	Population (2015)
Men	49.1%	49.5%
Women	50.9%	50.5%
<b>Age group</b>		
15–29	27.9%	27.3%
30–44	31.1%	32.0%
45–59	33.0%	33.9%
60–64	8.0%	6.8%
<b>Language</b>		
German	73.9%	74.0%
French	26.1%	26.0%
<b>Lives in:</b>		
Cities and agglomerations	79.1%	73.8%
Countryside	20.9%	26.2%
<b>Nationality</b>		
Swiss	80.4%	75.7%

Table B.2

Sample description: consumption pattern, green behaviour, and previous blackout experience

Green equipment	Yes	I don't know
Insulating window panes	82%	4%
Insulating walls	62%	15%
Solar heating	11%	5%
Photovoltaic panels	7%	3%
Minergie standard	13%	13%
Other energy saving equipment	21%	26%
Other renewable energy equipment	8%	19%
<b>Green behaviour</b>		
Light off when not needed	91%	
Heating off at night	65%	
Renewable electricity contract	44%	38%
<b>Electricity bill: awareness</b>		
<b>Yes</b>		
In charge of paying electricity bill	81%	19%
<b>Electricity bill per semester</b>		
Below 200 CHF	25%	
201–400 CHF	38%	
401–800 CHF	13%	
Above 800 CHF	3%	
I don't know		21%
<b>Blackout experience</b>		
Short blackout at home	27%	
Short blackout at work	10%	
Long blackout at home	21%	
Long blackout at work	8%	

Tab. B.3

Sample description: evaluation of statements concerning environmental or energy issues

Please evaluate each of these statements by stating how much you agree with it on a scale from 1 to 7. 1 means "Completely disagree", 7 means "Completely agree"	Average	Std. Dev.
Building new generation plants is essential to satisfy the increasing demand for electricity	4.74	1.70
Building new electricity generation plants from renewable energy sources is essential to satisfy the increasing demand for electricity	5.95	1.32
It is important to generate electricity using renewable energy sources	6.36	1.04
Most private buildings should be endowed with solar or photovoltaic panels	5.59	1.53
Wind turbines are noisy, which bothers the people who live near them	3.10	1.60
Wind turbines are dangerous for migrant birds and damage the fauna	3.32	1.55
Wind turbines spoil the scenery	2.86	1.69
I'm not worried about the risk of a nuclear accident in Switzerland	3.36	1.98

(continued on next page)

Tab. B.3 (continued)

Please evaluate each of these statements by stating how much you agree with it on a scale from 1 to 7. 1 means "Completely disagree", 7 means "Completely agree"	Average	Std. Dev.
I think the risk of a nuclear accident in Switzerland is very low	4.22	1.84
It is a good idea to dismantle all nuclear plants in Switzerland	5.14	1.96
It is dangerous to live close to a nuclear generation plant	4.60	1.92
It is dangerous to live close to a coal-fired generation plant	4.27	1.65
It is dangerous to live close to a gas-fired generation plant	3.88	1.60
Electricity can be imported from foreign countries with no risk	3.16	1.58
It is safe to import electricity from abroad	3.40	1.49
I feel worried about depending on foreign countries for energy supplies	4.40	1.64
Depending on foreign countries for our energy supplies endangers our economy	4.51	1.57
Carbon dioxide from burning coal, oil, and natural gas is causing global warming	5.83	1.31
I find blackouts annoying	4.94	1.67
Blackouts can be very costly for private companies	5.28	1.47
Blackouts can be very costly for households	4.05	1.73
I feel in danger when a blackout occurs at my place	2.45	1.50
I am worried about the risk of future increases in electricity prices	4.36	1.75
If global warming does occur, it would be bad for people and the environment	5.98	1.29
I am worried about the consequences of pollution	5.84	1.30
I am worried about the consequences of climate change	5.52	1.50
Everyone should behave in an environmental friendly way	6.36	1.03
As a society, we should be using less oil, coal, and natural gas in order to reduce environmental impacts on land, water, and air quality	5.92	1.28
It is important to save energy in everyday consumption	6.21	1.12
It is my responsibility to behave in an environmental friendly way	5.96	1.25

Tab. B4

Alternatives chosen in the DC experiment: general overview

	Nuclear	Mix	Wind	Hydro	Sun
Nr. of times this alternative was chosen	390 (5.5%)	2166 (30.8%)	1466 (20.8%)	1519 (21.6%)	1501 (21.3%)
Nr. of respondents who never chose this alternative	806 (80.1%)	222 (22.1%)	309 (30.7%)	304 (30.2%)	355 (35.2%)
Nr. of respondents who always chose this alternative	3 (0.3%)	42 (4.2%)	5 (0.5%)	6 (0.6%)	29 (2.9%)

Nr. of respondents: 1006; nr. of choice tasks completed: 7042.

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