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Abstract: Mexico City, that boasts the first place in electricity consumption among urban centers in the country, is actively advancing its energy transition by promoting renewable energies and tapping into its potential for solar and bio-energy. As households in emerging economies drive global energy demand, this study explores preferences of Mexico City's residents. Using a discrete choice experiment, 940 residents were presented with energy contracts featuring renewable energy sources, green job creation in the energy sector, renewable energy percentages in the energy mix, and electricity prices. Estimates reveal that respondents are willing to pay a 19.5% premium over the average price per kilowatt-hour if the energy source were exclusively solar and created 1000 green jobs. These findings offer insights for other megacities with similar challenges and renewable potential in pursuing a just energy transition.
Keywords: Renewable energies, just energy transition, green jobs, middle-income households, Mexico City
JEL Classification: Q42, Q48, Q51

Resumen: La Ciudad de México, que ocupa el primer lugar en consumo de electricidad entre los centros urbanos del país, promueve activamente su transición energética mediante el fomento de energías renovables, como la solar y la bioenergía. En un contexto en el que los hogares impulsan el consumo energético a nivel global, este estudio examina las preferencias de los residentes en la Ciudad de México. Usando un experimento de elección discreta, se le presentaron contratos energéticos a 940 residentes que incluían fuentes de energía renovable, creación de empleos verdes, porcentaje de energía renovable y precios. Las estimaciones muestran que los encuestados están dispuestos a pagar un 19.5% adicional sobre el precio promedio por kilovatio hora si la energía fuera exclusivamente solar y generara 1000 empleos verdes. Estos hallazgos ofrecen información útil para que otras megaciudades con desafíos similares y potencial en energías renovables avancen hacia una transición energética justa.
Palabras Clave: Energías renovables, transición energética justa, empleos verdes, hogares de ingresos medios, Ciudad de México

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1 Introduction

Emerging economies, and in particular their middle-income residents, are essential in reaching a global energy transition —a step towards a reduction in global greenhouse gas emissions. This is because these residents drive much of current and expected energy consumption worldwide, and therefore energy policies are expected to target these households (Gertler et al., 2016).

Mexico, as an emerging economy and with a large share of population classified as middle-income, has a role to play in the global energy transition. In particular, Mexican regulations provide private stakeholders and sub-national administrations with tools to promote renewable energies. In this respect, a number of state administrations have expressed their intentions to promote renewable energies through measures such as i) carbon taxes to power inputs (e.g. El Universal, 2020); ii) legal support to renewable energy companies (e.g. Romo, 2020); iii) mandating street lighting relying on solar energy (e.g. El Heraldo, 2020); iv) subsidizing small businesses to install clean energy technologies (e.g. Becerril, 2018; Gobierno del Estado de Aguascalientes, 2020); and waste management policies and initiatives (e.g. Gobierno de la Ciudad de México, 2021a).

In this context, generating information aiming to guide decisions at sub-national level becomes particularly relevant to achieve an energy transition in Mexico. This paper explores the preferences of middle-income residents of Alvaro Obregon Municipality —located in Mexico City and one of Mexico's wealthiest municipalities as it ranks in the highest decile with fewer poor and vulnerable people in the country (CONEVAL, 2020). We gathered data by means of a discrete choice experiment (DCE) responded by 940 middle-income residents random chosen in December, 2019. The DCE describes energy contracts trading renewable energy sources —solar, biomass, and a 50/50 mix—, creation of green jobs in the energy sector, amount of renewable energy in the consumed mixed, and electricity prices.

The motivation to explore preferences for creation of green jobs in the energy sector arises from the fact that energy transitions will displace jobs in industries relying on fossil fuels. Exploring whether residential electricity consumers —especially, middle-income residents— are willing to pay a premium in exchange for the creation of new green jobs is useful to design policies aiming to simultaneously increase generation of renewable energy and creation of jobs —which is essential for a just energy transition (Rosemberg, 2017).

The exploration of preferences for solar and biomass energies is rooted both in findings reported by previous studies and in Mexico City's potential to generate renewable energy. On the one hand, Mexico City has been double-blessed, with its abundance of biomass and sunshine —Mexico City is located in a region that has the largest potential of bio-methane from urban residues (Núñez, 2021) and that, at the same time, could cover current electricity consumption with solar energy (Zozmann et al., 2021). On the other hand, previous studies exploring willingness to pay (WTP) for alternative renewable energy sources have documented an empirical regularity: respondents to stated preferences studies report a significantly higher willingness to pay for electricity generated from solar than from biomass (Soon and Ahmad, 2015) —to the point that evidence is inconclusive on whether there is actually a willingness to pay for biomass energy (Sundt and Rehdanz, 2015; Yoo and Ready, 2014).

This paper's estimates —which arise from random parameter logit specifications— illustrate that middle-income residents in Mexico City are willing to pay 10.9% over the price per kilowatt-hour on a monthly basis —i.e., regardless the source. However, if the electricity source is exclusively solar, they are willing to pay 12.8% over the average price per kilowatt-hour. Additionally, they are willing to pay 19.5% over the average price per kilowatt-hour if the energy source were exclusively solar and created 1000 green jobs in the energy sector. Conversely, respondents exhibit a negative willingness to pay for biomass energy, a finding consistent with previous studies (e.g. Gracia et al., 2012; Cicia et al., 2012; Danne et al., 2021; Martínez-Cruz and Núñez, 2021; Yoo and Ready, 2014).

With its focus on preferences of middle-income residents in a megacity of an emerging economy, this paper contributes to a recent literature exploring preferences of electricity consumers for renewable energy amid energy transitions at national scales. This literature has mostly focused on residents of developed countries. For instance, Kanberger and Ziegler (2023) explore preferences of German residents for different strategies to reach an environmentally friendly and fair energy transition in Germany. Focusing on residents in the Higher-Normandy Region, France, Faulques et al. (2022) document that residents in areas where production of renewable energy would generate negative externalities report lower willingness to pay for renewable energy in comparison to residents in areas where negative externalities are not generated —a finding that they label as principle of territorial distributive justice. Focusing on Swiss residents, Motz (2021a) and Motz

(2021b) have explored, respectively, social acceptance of new infrastructures associated with advancing an energy transition in Switzerland, and preferences with respect to the trade-off between security of energy supply and source of energy involved in pursuing an energy transition.

This paper's focus and approach is closest to the work of Martínez-Cruz and Núñez (2021). They have used a DCE to explore preferences of middle-income urban residents in Aguascalientes —a mid-sized city located in the semi-arid region of Mexico. Indeed, this study use a similar DCE design because it aims to draw conclusions with respect to differences (or similarities) among preferences of Mexico City's residents and preferences of Aguascalientes' residents —which is useful to inform not only Mexico City's energy transition but the country's transition as well.

The rest of this manuscript is organized as follows. Section 2 reports on previous energy renewable studies that, by DCEs, have explored preferences for jobs and/or renewable energy resources. Section 3 describes Mexico City's potential to generate renewable energy and the efforts that are currently in place to pursue such generation. Section 4 describes the theoretical and empirical strategies supporting the analysis in this study. Section 5 explains the DCE design, describes the data collection strategy, and reports descriptive statistics. Section 6 reports econometric specifications and welfare estimates. Section 7 places this paper's findings in context and concludes.

2 Related discrete choice experiments

This section places the contribution of this study at the intersection of two strands of literature documenting stated preferences via discrete choice experiments (DCEs). The first strand refers to a nascent, rapidly grown exploration of preferences for aspects considered relevant to reach just energy transitions. The second strand refers to the exploration of preferences for both job creation and renewable energy sources —this ongoing exploration was started prior to, and runs parallel to, DCEs exploring preferences for just energy transitions.

2.1 Aspects relevant to just energy transitions

DCEs exploring aspects relevant to just energy transitions have focused on European countries. Particular attention has been paid to Germany (e.g. Danne et al., 2021; Kanberger and Ziegler, 2023; Knoefel et al., 2018; Sagebiel et al., 2014; Wu et al., 2022); followed by France (Faulques et al., 2022; Wu et al., 2022), Switzerland (Motz, 2021a,b), and Poland (Aruga et al., 2021; Wu et al., 2022). In addition, Wu et al. (2022) reports a comparison across ten countries —Croatia, France, Germany, Ireland, Italy, Poland, Portugal, Spain, Sweden, and UK.

Attributes explored by these DCEs reflect the fact that European countries' energy transitions are underway. For instance, Aruga et al. (2021) explore preferences of Polish residents for the number of years that an energy transition would take to be completed; Kanberger and Ziegler (2023) explore whether German residents would prefer that the energy transition encompasses the phase-out of all nuclear power plants by 2022; and Danne et al. (2021) explore whether a discount on annual tariffs would incentivize German residents to switch from conventional energy to renewable energy. Motz (2021a) and Motz (2021b) explore Swiss residents' acceptance of blackouts because a major challenge to fully adopt renewable energies is the reliability of electricity supply due to the volatility of renewable energy sources.

Another line of inquiry by these studies explores preferences for new business models, some of which are becoming a reality amid energy transitions. For instance, Wu et al. (2022) explore whether citizens in ten European countries are willing to invest in energy projects through cooperatives and crowdfunding platforms —an exploration carried out by Sagebiel et al. (2014) on German residents and only for energy cooperatives. Wu et al. (2022)'s DCE describes contracts in terms of smallest amount required to invest, annual return to investment, size of energy plant, and duration of contract. Residents may have preferences over features determining corporate governance as they ponder whether to directly and actively be involved in such business models. Thus, Sagebiel et al. (2014) and Knoefel et al. (2018) explore German residents' interest in participating in a utility's decision-making process, and whether transparency in how energy prices are calculated is a relevant component in taking such a decision.

In terms of social aspects relevant to an energy transition, Kanberger and Ziegler (2023) explore two attributes: whether low-income households would receive financial support to face the energy transition, and whether households bearing the costs of the energy transition would do so in proportion to their income or in proportion to their energy consumption. In addition, Faulques et al. (2022) highlight the need for a territorial distributive justice as part of the energy transition as residents in areas facing negative externalities due to renewable energy production (e.g., wind turbines and anaerobic digestion units) tend to have a lower WTP than residents not facing such externalities in the Higher Normandy Region, France. Aruga et al. (2021) is, within this strand of the literature, the only study that explores preferences for creation and displacement of jobs, and thus this work describes their approach in the next subsection.

2.2 Job creation and renewable energy sources

While studies described in the previous subsection place their contributions as part of the explorations supporting an energy transition in the residential sector, the attributes under analysis are not as relatable to residents in Mexico. This is so because Mexico has not fully launched its energy transition and, therefore, conversations around e.g., timing for completion of transition or participation in business models are foreign to Mexican residents at this moment. In contrast, a consideration of the highest importance in the Mexican context is job creation in the renewable energy sector as 117,000 workers employed by the state-owned oil company will directly face the economic consequences of an energy transition.

Thus, this subsection covers DCEs studies exploring preferences for job creation and renewable energy sources. Table 1 reports a summary that classifies studies in three groups. The first panel of Table 1 describes five studies that this manuscript is the closest to in terms of design of DCE as these studies explore preferences for both job creation and renewable energy sources (Kosenius and Ollikainen, 2013; Martínez-Cruz and Núñez, 2021; Oluoch et al., 2021, 2022; Yoo and Ready, 2014). The second panel of Table 1 describes four studies that, keeping fixed the renewable energy source under consideration, explore preferences for job creation (Aruga et al., 2021; Bergmann et al., 2008; Longo et al., 2008; Soliño et al., 2012). The third panel of Table 1 describes eight studies that, without exploring preferences for job creation, have studied preferences for bio- and solar energy. In selecting this last group of studies, this section prioritized those documenting that bioenergy tend to be the least preferred of renewable energies to the point that, not infrequently, respondents report negative WTP —a finding that this manuscript documents and elaborates in the discussion section.[1]

There are three main takeaways from studies in Table 1. The first one is that, when

[1] There is a long-standing literature on stated preferences for residential renewable electricity, and the review of previous studies —particularly of those reported in the third panel of table 1— is not exhaustive. Interested reader is referred to six meta-analysis studies: Cerda et al. (2024); Chaikumbung (2021); Pokhrel (2016); Ma et al. (2015); Soon and Ahmad (2015); Sundt and Rehdanz (2015).

pondering job creation and renewable energy sources simultaneously, respondents report a positive and statistically significant WTP for creation of new jobs. This finding holds for residents in both developed and emerging economies —e.g. Finland (Kosenius and Ollikainen, 2013), USA (Yoo and Ready, 2014), Mexico (Martínez-Cruz and Núñez, 2021), Kenya (Oluoch et al., 2021), and Rwanda (Oluoch et al., 2022). The second takeaway from Table 1 is that, when pondering energy projects involving a specific renewable source, respondents also report a positive WTP for job creation. This finding has been documented only in European contexts —e.g., Poland (Aruga et al., 2021), Scotland (Bergmann et al., 2008), England (Longo et al., 2008), and Spain (Soliño et al., 2012). The third takeaway is that while respondents are willing to pay for renewable energy, they report the lowest WTP for bio-energy —sometimes even negative. This finding holds across the three groups of studies covered in Table 1 and has been reported by Chaikumbung (2021), who carried out a meta-analysis of 91 studies.

Table 1: Studies using discrete choice experiments to document preferences for job creation (or job displacement) and renewable energy (RE) sources.

Study	Location	Attributes levels				WTP for	
		RE	Jobs	Price	Other	Bioenergy	Jobs
Preferences for job creation (or job displacement) and renewable energy sources							
Kosenius and Ollikainen (2013)	Finland	Increase in RE shares from 28% to 38% (source: wind, crop, wood, hydro)	New local jobs (wind: 800, 100; crop: 1,400, 400; wood: 5,000, 2,500, hydro: 500, 20)	Change in annual electricity price (5, 30, 80, 160 Euros)	Local biodiversity (no change, deterioration, improvement) Carbon emissions (-99% to -60%)	140 to 261 (2008) Euros/HH/year, depending on region Energy produced with crop biomass is the least preferred	20 (2008) Euros/HH/year for 1,000 local jobs
Martínez-Cruz and Núñez (2021)	Aguascalientes, México	Source: Solar, biomass, 50-50 mix; and share of RE: 10%, 20%, 30%	New jobs in RE sector (100, 1,000, 2,000)	% increase in electricity bill (5%, 20%, 40%)	None	-2.58 (2019) USD/HH/ bimonthly Biomass energy is the least preferred	2.03 (2019) USD/HH/ bimonthly for 1,000 new jobs in RE sector
Oluoch et al. (2021)	Kenya	Source: Solar, wind, geothermal, biomass	New jobs (<10, 10-20, >20)	Yearly tax on renewable energy projects (300, 600, 900 Ksh)	Ownership of energy company (public, private) Impacts on environment (low, medium, high) Distance and visibility of project to respondent's home (<10km and visible, <10 km and not visible, >20 km and not visible)	12.31 (2019) USD/HH/year Biomass energy is the least preferred	5 to 7 (2019) USD/HH/year for 10 to 20 jobs
Oluoch et al. (2022)	Rwanda	Source: Solar, small hydro, geothermal, biomass	New jobs (<10, 10-20, >20)	Yearly tax on renewable energy projects (3000, 6000, 9000 Rwf)	Ownership of energy company (public, private) Impacts on environment (low, medium, high) Distance and visibility of project to respondent's home (<10km and visible, <10 km and not visible, >20 km and not visible)	11.97 (2019) USD/HH/year Biomass energy is the least preferred	17.86 (2019) USD/HH/year for 10 to 20 jobs

Yoo and Ready (2014)	Pennsylvania, USA	% of electricity generated from RE source: wind (2.8%-4.6%); solar (0.5%-1.4%); biomass (1.5%-2.8%); and other unspecified source (3.2%-4.7%)	Impact on jobs in Pennsylvania (-3,000, 0, +3,000)	Additional cost to household through higher monthly electricity bills and/or taxes (0 to 25 USD)	None	-0.32 to 2.09 (2010) USD/household/ month, depending on econometric model Biomass energy is the least preferred	1.88 to 5.48 (2010) USD/HH/ month for gains in up to 3,000 jobs 6.71 to 35.91 (2010) USD/HH/ month to avoid loss of up to 3,000 jobs
		Preferences for job creation (or jobs displacement) —no attributes referring to renewable sources					
Aruga et al. (2021)	Poland	None	Impact of policy on employment (-16,000, -8,000, 0, +8,000, +16,000)	Change in monthly electricity bill (-40%, -20%, 0, +20%, +40%)	Reduction in carbon emissions (20%, 25%, 30%, 35%, 30%) Energy independence (40%, 50%, 60%, 70%, 80%) Time to transition (4 yrs, 8 yrs, 12 yrs, 16 yrs, 20 yrs)	N/A	0.00162% increase in monthly bill for one job
Bergmann et al. (2008)	Eight council districts of Scotland	None	New local long-term jobs (1-3, 8-12, 20-15)	Annual increase in household electricity bill (0, 7, 16, 29, 45 GBP)	Impacts on landscape (none, low, moderate, high) Impacts on wildlife (none, slight improvement, slight harm) Air pollution (none, slight increase)	N/A	1.08 GBP for creation of each new permanent job
Longo et al. (2008)	Bath, England	None	Change in number of employees in the electricity sector (- 1,000, 0, + 1,000)	Increase in yearly electricity bill (6.5, 16, 25, 38 GBP)	Annual reduction in GHG emissions due to RE increase (1%, 2%, 3%) Annual length of electricity shortages in minutes (30, 60, 120);	N/A	0.02 GBP per additional job in the energy sector
Soliño et al. (2012)	Northwest region of Spain	None	New jobs in rural areas (3,000, 6,000)	Two versions: annual (30, 60, 90, 120 Euros); and bimonthly 5, 10, 15, 20 Euros)	Reduction in CO2 emissions (7%,75%);	Better off if elect. is generated from forest bio (no trade-off with other RE sources in DCE)	22.38 Euros per 3000 new rural jobs

		Preferences for renewable energy —no attributes referring to job creation (or job displacement)					
Borchers et al. (2007)	New Castle County, Delaware, USA	Source: wind, solar, biomass, farm methane, generic green energy source	None	Increase in monthly electricity bill (5, 10, 15, 20, 30 USD)	% of respondent's monthly electrical usage (10%, 25%)	-2.22 to 10.59 USD per month; Least preferred out of 5 options	N/A
Cicia et al. (2012)	Italy	Source: wind, solar, biomass, and nuclear	None	Changes in bimonthly electricity bill: 0, 5, 10, 15, 20, 30 Euros for all sources but nuclear; and 0, -5, -10, -15, -20, and -30 Euros for nuclear source	None	-66.25 to 40.06 Euros bi-monthly Least preferred out of 3 RES	N/A
Danne et al. (2021)	Germany	Source: solar, biogas, wind, RE-mix; and share of RE: 40%, 60%, 80%, 100%	None	Monthly tariff price, including switching bonus (70, 75, 80, 85 Euros)	Switching bonus (30, 60, 90, 120 one-time payment in Euros) Price guarantee (0, 6, 12 months)	-0.407 Euros per kWh; Least preferred out of 4 options	N/A
Faulques et al. (2022)	Higher Normandy Region, France	Share in energy mix of i) wind power (low: 6% to 8%, average: 10%, high: 12%); ii) photovoltaic panels (low: 2% to 6%, average: 8%, high: 10%); iii) anaerobic digestion (low: 2% to 6%, average: 8%, high: 10%)	None	Price increase per 100 kWh (0, 1, 2, 4, 6 Euros)	None	0.90 to 1.90 Euros per 100 kWh Least preferred out of 3 options	N/A

Gracia et al. (2012)	Zaragoza, Spain	% of respondent's electrical usage from wind (16%; 18%; 21%; and 26%), from solar (6%; 10%; 14%; and 18%); and from biomass (2%; 3%; 5%; and 6%)	None	Price per kWh (0.17, 0.21, 0.24, 0.28 Euros)	Region of origin (Aragon, unknown)	-0.0044 Euros per kWh Least preferred out of 3 options	N/A
Kaenzig et al. (2013)	Germany	% of electricity generated by source: coal (0 or 60%), natural gas (0 or 25%), biomass (5 or 15%); wind (0, 5, 50 or 100%); solar (0 or 5%), hydro (0, 5, or 30%) and nuclear (0 or 25%), and unknown origin (0 or 25%)	None	Monthly electricity cost (50, 55, 60, 65, 70 Euros)	Provider (major national, medium sized regional, municipality, independent marketer) Location of electricity generation (Region, Germany, Switzerland, Eastern Europe) Ecolabel (ok power, TUV, Gruner Strom, no certification) Price Guarantee (none, 6, 12, 24 months) Cancellation period (monthly, quarterly, semi-yearly, yearly)	Least preferred out of 6 options	N/A
Komarek et al. (2011)	Michigan State University	% of electricity generated by source: coal (0-100%), natural gas (0-100%), biomass (0-30%); wind (0-10%); solar (0-10%), and nuclear (0-50%)	None	Additional semester fee (25, 50, 100, 150 USD)	Energy conservation (minimal, moderate, extensive) Carbon emissions reduction (15%, 17%, 19%, 21%, 23%) Year reduction is achieved (2015, 2020, 2025)	2.99 to 4.18 USD biannual fee Least preferred among 3 RE sources	N/A
Vecchiato and Tempesta (2015)	Veneto, Italy	Source: solar photovoltaic, biomass from agriculture, biomass from forest	None	Increase in monthly electricity bill (0, 2, 5, 10 Euros)	Size of the power plant (big, small) Distance of power plant from interviewees' living area (1, 3, 10 kms)	2.05 and 4.43 Euros per month; Forest biomass is preferred to agricultural biomass	N/A

Source: Own elaboration.

3 Residential Energy Consumption and Renewable Energy in Mexico City

Mexico City (CDMX) is the third-largest residential consumer of electricity in the country (IADB, 2019) below the states of Nuevo León and México State. In 2018, the residential sector in CDMX consumed 20% of the city's total electricity demand (almost 17,000 Gigawatt hours), and 5% of the electricity consumed by the national residential sector. When adding the residential electricity consumption of the State of Mexico, whose economic sectors are linked to CDMX, the share that the residential sector represents is 12% at the national level.[2]

CDMX does not generate as much energy as it consumes, and only a very small portion of what is consumed is generated with renewable sources (IADB, 2019; SENER, 2019). In 2018, CDMX generated 1,178 Gigawatt hours (GWh) of electricity; and State of Mexico, 5,781 GWh. Together, these numbers represented only 42% of CDMX's electricity consumption. Only 166 GWh were produced from renewable energy sources —mostly hydro-power—, which implies that only a small fraction of electricity consumed by the residential sector in CDMX comes from a renewable source.

However, CDMX has tremendous renewable energy possibilities that is currently pursuing (Dirección General de Desarrollo y Sustentabilidad Energética, 2019). For instance, the solar energy potential in Central Mexico —the region where Mexico City is located— is enough to produce as much electricity as it is currently consumed (Zozmann et al., 2021).[3] IADB (2019) has identified three major renewable sources to generate electricity in Mexico City: i) distributed solar generation — Hancevic et al. (2017) calculate less than 1600 KWh year per 1KW of distributed photovoltaic system installed—; ii) solar thermal (water heating); and iii) biogas-based turbines in wastewater treatment plants. With respect to bio-energy, Núñez (2021) has estimated that the Central region has the largest potential of bio-methane from urban residues —with more than 18 billion cubic feet per year, which can substitute imported natural gas used for electricity.

It is worth noticing that there have been a series of energy and sustainability strategies in CDMX aiming to supply electricity from renewable energy sources. One of the projects launched in 2019 is the "Ciudad Solar" Program, which aims to provide 2400 businesses

[2] The State of Mexico serves as a neighboring state that encircles a significant portion of CDMX, each being distinct entities within the country.
[3] Central Mexico is conformed by CDMX, State of Mexico, and several municipalities from the states of Hidalgo, Guerrero, Michoacan, Morelos, and Puebla.

and 300 public buildings with solar panels, as well as a total of 153,851 solar water heaters for homes and businesses in the 2019-2024 period. It also seeks to bring solar technology to transportation, as one strategy consists of 100% of the Ligero Train's energy consumption coming from a Photovoltaics (PV) system. This program is expected to create 10,700 new jobs, as well as training for the installation of solar panels (Dirección General de Desarrollo y Sustentabilidad Energética, 2019). Another program by Secretaría de Desarrollo Económico (2021) aims to promote the use of PV systems in micro, small and medium-sized enterprises in Mexico City. The support for these enterprises includes both technical and financial advice and economic support up to 40% for solar heaters and up to 20% for PV systems. One more project is the installation of PV systems on the roofs of the central wholesale market (Central de Abastos). Some previous assessments mention that this project will reduce almost 14 thousand tons of GHG and save Mexican peso (MXP) 73.5 million (José, 2021).

As Mexico City has such significant solar potential, and initiatives will be undertaken to exploit it, the city also has access to vast amounts of energy generated by its urban solid wastes, which can be used simultaneously to target pollution, among other benefits. It is well known that such large cities face waste management problems. For example, it is estimated that around 13 thousand tons of solid waste are generated per day in CDMX (Gobierno de la Ciudad de México, 2021a), of which 68% goes to landfills that are already working beyond their installed capacities such as landfill Bordo Poniente, which reached its capacity limit in 2008 (Gutierrez Galicia et al., 2019). The remaining urban solid waste is used for recycling (15%), composting plants (11%) and alternative fuels (6%) (Gobierno de la Ciudad de México, 2021a). Just below New York City, CDMX is the second largest solid waste producer in the world and approximately 49.5% of these residues correspond to the organic fraction (Kennedy et al., 2015; Durán Moreno et al., 2013). This fraction not only can be used as compost but can also be transformed to biogas for direct consumption or biomethane for electricity generation. For instance, Núñez (2021) finds that the Central region, mainly due to Mexico City, has the largest potential of biomethane from urban residues, with more than 18 billion cubic feet per year, which can substitute imported natural gas for electricity. In general, using urban waste may bring: 1) environmental benefits as landfills or incinerators would be less used, which can help to mitigate soil and water contamination, air pollution, and greenhouse gas emissions; 2) resource conservation by reducing the need for new raw materials; 3) economic benefits by creating jobs in waste management, reducing waste disposal costs, and generating revenue through the sale of recycled materials; 4) energy savings since it takes less energy to recycle materials than to create new ones from scratch; 5) community benefits by providing them with access to affordable and sustainable products and materials, improving public health, reducing the environmental impact of waste disposal, and importantly for the aim of this paper, generating local energy (Escamilla García et al., 2016; Gutierrez Galicia et al., 2019; Núñez, 2021).

As for the solar case, there has been some plans to use urban residues as a source of energy. The city's waste management plan includes processing 1,500 tons per day for energy production by 2025, but the city is still far from this goal (Gobierno de la Ciudad de México, 2021b). For instance, the plant located in Azcapotzalco generates more than 400 permanent jobs and can process 1,000 tons of residues per day, but the organic part is mainly used for compost, missing out on energy potential (Gobierno de la Ciudad de México, 2021c). A promising case is the projected plant at Aragón, which plans to process 1,200 tons per day and a significant portion will be allocated to obtain bioenergy (Expansión, 2022). The city already has a pilot organic waste biogas plant operating in the far south, which processes 4 tons of residues per day and can generate up to 175 Kilowatt-hour (kWh) per day, demonstrating the potential of this sector and even more if it was located near the city center (Energías Renovables, 2017). Another plan is to use pallets of hydro-carbon from biomass the organic fraction of urban solid waste to substitute the coal used in the Petacalco thermoelectric plant of the Federal Electricity Commission (CFE) (Hernández, 2021; Gaceta UNAM, 2021; Lara, 2017).

4 Theoretical and empirical approaches

4.1 Random Utility Model

The Random Utility Model (RUM) provides theoretical support to the empirical analysis of discrete choice experiments (see Train, 2009). The departure point of the RUM is that, when faced to J mutually exclusive *energy contracts*, electricity consumer i chooses the alternative that provides him/her with the highest utility. A consumer's indirect utility from each contract is denoted as U_{ij} for $i = 1, 2, ..., I$ and $j = 1, 2, ..., J$. The consumer is assumed to know his/her own utility function with certainty. The researcher, however, cannot fully observe each U_{ij}. Thus, from the researcher's point of view and once a linear indirect utility function is assumed, U_{ij} can be expressed as

$$U_{ij} = V_{ij} + e_{ij} = \beta' x_{ij} + \epsilon_{ij} \ , \tag{1}$$

where V_{ij} is the component observed by the researcher; x_{ij} is a $(M + 1) * 1$ column vector denoting M contract-specific attributes and the contract-specific intercept; β is a $(M + 1) * 1$ column vector representing the contract-specific intercept, preferences for attributes describing the contracts; and ϵ_{ij} represents the purely random heterogeneity that the researcher is unable to observe.

If a consumer chooses the energy contract associated with the highest utility, then the consumer *i* chooses U_i^{max}, where

$$U_i^{max} = \max\{U_{i1}, U_{i2}, \dots, U_{iJ}\} \ , \tag{2}$$

The willingness to pay (WTP) for the energy contract associated with the highest utility is expressed as the monetary value of the utility derived from U_i^{max}, i.e.,

$$WTP_i = \frac{U_i^{max}}{\beta_p} \ , \tag{3}$$

where WTP_i is consumer *i*'s WTP; and β_p is the price preference parameter. Under the assumption that indirect utility is linear in attributes, including income, β_p is the negative of the marginal utility from income.

Under the assumptions embedded in equation (1), a researcher cannot observe U_i^{max} as defined in equation (2). A researcher can only make statements in terms of expected utilities which are calculated over the error term ϵ_{ij}, i.e.

$$E(U_i^{max}) = E_\epsilon[\max\{V_{i1}, V_{i2}, \dots, V_{iJ}\}] \ . \tag{4}$$

Under the assumption that ϵ_{ij} follows a type I extreme value distribution, the expected maximum utility can be calculated through the log sum formula,[4] i.e.

$$E(U_i^{max}) = ln \sum_{j=1}^{J} \exp{(V_{ij})} \ . \quad (5)$$

Accordingly, statements involving welfare measures are made in expected terms. For a before (b) and an after (a) situations —where after implying a change in the available alternatives— the expected value of the compensation variation (CV) due to the change in consumer i's utility is expressed as

$$E(CV_i) = \frac{1}{-\beta_p}\left(E_\epsilon\left(U_i^{max,a}\right) - E_\epsilon\left(U_i^{max,b}\right)\right)$$
$$= \frac{1}{-\beta_p}(ln \sum_{j=1}^{J} \exp\left(V_{ij}^a\right) - ln \sum_{j=1}^{J} \exp{(V_{ij}^b)}) \ . \quad (6)$$

The marginal willingness to pay (MWTP) can be derived from equation (6) as follows. Assume attribute q changes in a non-marginal fashion across all alternatives —i.e., $q^a = q^b + \Delta q$ is the level of q after Δq has been added to q^b. Introduce the change in q in equation (6) and, because such a change occurs across all alternatives, factor it.[5] The expected CV can be expressed as follows

$$E(CV_i[\Delta q]) = -\Delta q \frac{\beta_q}{\beta_p} \ , \quad (7)$$

where β_q is the marginal utility from q.

Equation (7) reduces to the WTP for a marginal change across alternatives when $\Delta q = 1$ —i.e., when the change in q is marginal, and

$$E(MWTP_i) = -\frac{\beta_q}{\beta_p} . \quad (8)$$

Equation (8) can be interpreted as the ratio of the marginal utility from the attribute that changes and the negative of the marginal utility from income.

[4] Ben-Akiva (1973) and McFadden (1973) independently developed pioneer derivations of the log sum formula.
[5] Further details can be found in Haab and McConnell (2002).

4.2 Econometric model

Empirical estimations of the parameters required in the calculation of the expected MWTP (i.e., $\hat{\beta}_q$ and $\hat{\beta}_p$) can be obtained via a conditional logit econometric specification. The departure point of this empirical model is the same as establishing the theoretical expectations of the welfare measures under discrete choice modelling —i.e., ϵ_{ij} is distributed according to a type I extreme value distribution. Under this assumption, the probability that consumer *i* chooses energy contract *j* is expressed as follows

$$\begin{aligned} P_{ij} &= Pr[V_{ij} + \epsilon_{ij} > V_{ik} + \epsilon_{ik} \;\; \forall k \neq j] \\ &= Pr[\epsilon_{ij} > V_{ik} - V_{ij} + \epsilon_{ik} \;\; \forall k \neq j] \\ &= \frac{e^{V_{ij}}}{\sum_{k \in J} e^{V_{ik}}} \\ &= \frac{e^{\beta' x_{ij}}}{\sum_{k \in J} e^{\beta' x_{ik}}} . \end{aligned} \tag{9}$$

A conditional logit (CL) specification faces two limitations to model empirical discrete choice data (Train, 2009). First, a CL can represent systematic variation (i.e. taste variation that is related to observed characteristics) but not random taste variation (i.e. differences in tastes that cannot be linked to observed characteristics). Second, the estimation of the CL probabilities implies proportional substitution across alternatives —more flexible, more realistic patterns cannot be fitted with a CL model.[6]

The random parameters logit (RPL) results from adapting the CL model to incorporate non-systematic heterogeneity in preferences and discard the proportional substitution across alternatives. The RPL turns out to be a highly flexible model that can approximate any random utility model (McFadden and Train, 2000).

The RPL probabilities are the integrals of standard logit probabilities over a density of parameters. That is, keeping in mind equation (9), a RPL is a model whose choice probabilities can be expressed in the following form

$$P_{ij} = \int \frac{e^{\beta' x_{ij}}}{\sum_{k \in J} e^{\beta' x_{ik}}} f(\beta) d\beta \, . \tag{10}$$

where $f(\beta)$ is the density function. The researcher does not know this density. Instead, it

[6] A third limitation is that a CL is not fitted to capture correlation over time (Train, 2009).

is simulated via the Method of Simulated Moments (McFadden and Train, 2000) —notice that such simulation implies that a number (e.g. 1,000) of density functions are simulated to decide which one is the one fitting the best the empirical distribution of stated choices reported by consumers. The RPL probability is a weighted average of the logit probabilities evaluated at different values of β, with the weights given by the density function $f(\beta)$. In statistical terms, the weighted average of several functions is called a mixed function. Consequently, a RPL is a mixture of the logit function evaluated at different $\beta's$ with $f(\beta)$ as the mixing function. As is customary in Discrete Choice Experiments (DCE), the Random Parameter Logit (RPL) specification includes attributes other than price as independent variables.

5 Survey methods and data

5.1 Discrete choice experiment

Like any discrete choice experiment (DCE), this one starts with the selection of attributes and their corresponding levels. Once these are determined, different scenarios are designed to present to the respondents. The scenarios of the DCE were designed according to an orthogonal main effects strategy (see Aizaki, 2012). The DCE contains nine choice sets, all of which were presented to respondents. These nine scenarios yield a D-efficiency of 95.2%.[7] Each choice set includes three alternatives described in terms of four attributes, and a status quo alternative.[8] The respondents were asked to choose one alternative in each choice set.

Table 2 lists the four attributes of the discrete choice experiment (DCE) and their corresponding levels. The attributes included in the DCE are i) renewable energy source, ii) % of renewable energy sources in current electricity mix, iii) new jobs in renewable energy sector, and iv) % increase in self-reported bimonthly electricity bill. The inclusion of renewable energy sources as well as their share is key for this study's purpose.

[7] D-efficiency, or design efficiency, is a measure of how well the experimental design can estimate the parameters of interest with the smallest possible standard errors. It evaluates the quality of a design based on the precision of the estimates it yields, optimizing the arrangement of choice sets to maximize the statistical information extracted from respondents' choices Bliemer and Rose (2011).

[8] Concerns have been raised about incentive compatibility of discrete choice experiments. There is evidence suggesting that lack of incentive compatibility in DCE yields overestimation of stated WTP for public goods. For private goods, as the one under analysis in this paper, evidence suggest that estimates in non-incentive compatible contexts are within the 95% confidence interval of estimates in which incentive compatible mechanisms are in place. The reader is referred to Johnston et al. (2017), a contemporary guidance for stated preference studies, and to Taylor et al. (2010), who report evidence supporting the claims in this footnote.

Respondents may be willing to pay a premium for renewable electricity because they value it regardless of its source. It is also possible that this WTP arises from respondents' preferences for a specific renewable energy source. A third alternative is that consumers have preferences for a larger share of renewable electricity while they attach a premium to a specific source. By including both attributes, this DCE is designed to empirically test which one of these three cases hold in the sample. Borchers et al. (2007), Gracia et al. (2012), and Yang et al. (2016) are instances of previous studies that have also included both renewable energy sources and its share as attributes in their DCE.

Table 2: Attributes and levels in discrete choice experiment.

Attributes	Levels
Renewable energy source (RES)	Solar, biomass, and mix (50/50)
% of RES in current electricity mix	10%, 20%, and 30%
New green jobs (new jobs in RE sector)	100, 1,000, and 2,000
% increase in self-reported bimonthly electricity bill	5%, 20%, and 40%

Source: Own elaboration with information in Martínez-Cruz and Núñez (2021)

The first attribute in Table 2 refers to renewable energy sources. WTP of residential users has been documented to vary depending on the source of the renewable energy. In particular, WTP is higher for solar and wind energies and lower for biomass and hydropower. These empirical results have been reported both by documents consolidating the relevant literature (Ma et al., 2015; Sundt and Rehdanz, 2015), and by individual studies focusing, for instance, on Spanish (Gracia et al., 2012), Danish (Yang et al., 2016), American (Borchers et al., 2007), and Italian consumers (Vecchiato and Tempesta, 2015; Cicia et al., 2012).

In the DCE, renewable energy originates from either solar source, or biomass, or a 50/50 mix. This way of controlling for energy source follows strategies pursued by, for instance, Cicia et al. (2012); Kosenius and Ollikainen (2013); Vecchiato and Tempesta (2015). Studies including similar sources than the used in this study have documented a larger WTP for solar over wind and biomass (e.g. Borchers et al., 2007; Gracia et al., 2012; Cicia et al., 2012; Vecchiato and Tempesta, 2015), and when hydropower is included, this is preferred to the rest (Botelho et al., 2018).

The second attribute in the DCE refers to the share of renewable energy sources in current electricity mix —10%, 20% or 30%. These values are relevant under the light of the Mexican Energy Transition Law (ETL). Specifically, the ETL mandated that 10.9% of electricity consumption in Mexico should come from clean energies for large consumers. In addition, 30% of total electricity generation in Mexico must come from clean energies by 2021. Indeed, the current administration claims that Mexico has already an installed capacity to generate up to 31% from renewable energy sources (Forbes, 2020).

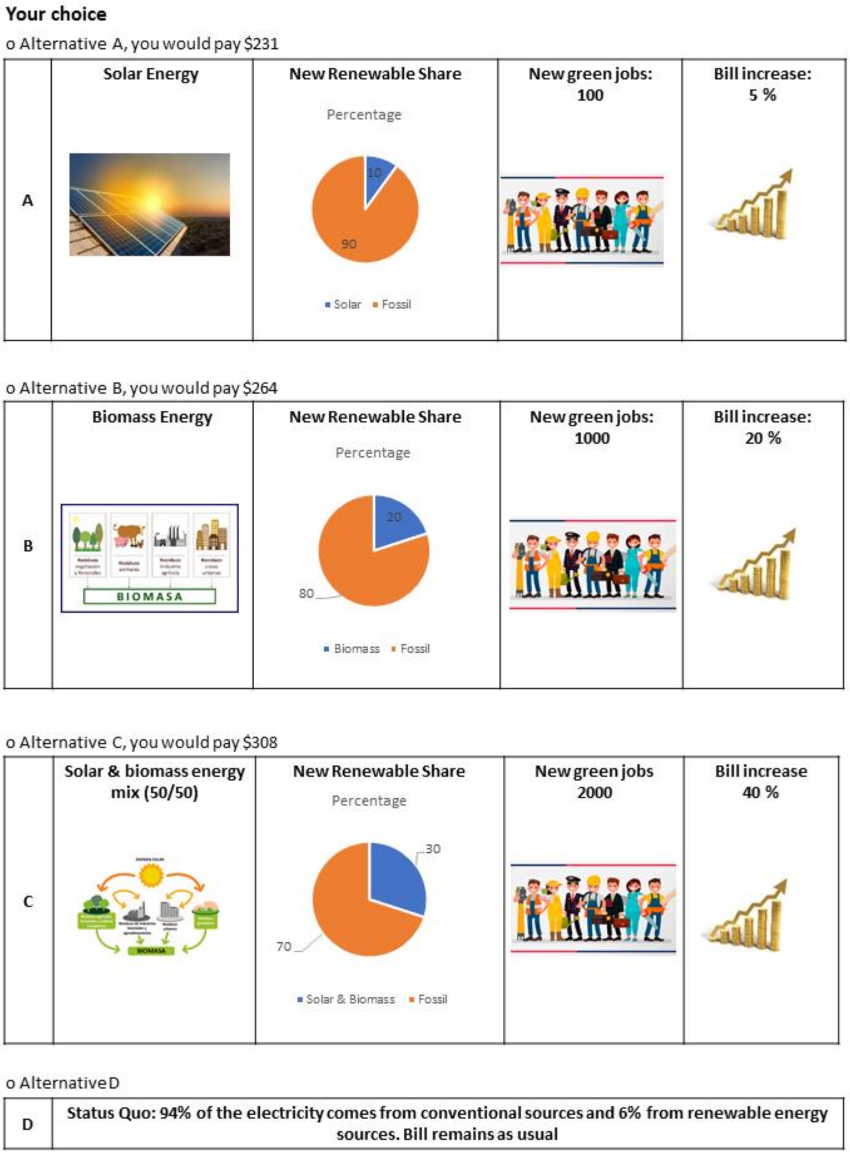
The third attribute in the DCE refers to the number of new jobs created in the renewable energy sector —which are called green jobs. This attribute takes values 100, 1,000, or 2,000. The jobs would be created in Mexico City, including the capital city. Strictly speaking, the creation of jobs is not an attribute of the electricity service. If respondents' utility positively depends on number of green jobs, then pursuing the adoption of renewable energy sources may yield a double dividend —generation of less greenhouse emissions per kWh and the creation of jobs that are valued by urban residents. A positive WTP for new jobs has previously been documented by DCE studies (Kosenius and Ollikainen, 2013; Bergmann et al., 2006; Soliño et al., 2012).

The fourth attribute in the DCE is the price attribute. In contrast to studies reviewed in Table 1, which describe the price attribute as changes in absolute values, this DCE presents it a percentage increase in respondents' self-reported monthly electricity bill. This pivot design has been employed by studies such as Amador et al. (2013) and offers the advantage of generating greater variation in the price attribute—while keeping this variation within a reasonable range of absolute values. In other words, if respondents calculate the final price after the increase, the resulting bill will, on average, remain below the highest bill paid among households with similar characteristics, as reported in the National Survey of Household Income and Expenditure (INEGI, 2020).

Price attribute takes values 5%, 20%, and 40%. These range of values is within the ranges presented in previous DCE studies (e.g. Longo et al., 2008; Kosenius and Ollikainen, 2013). Also, an increase of 40% represents an average increase of 80 MXP per month, which represents 1.95% of the average household head's income in CDMX (INEGI, 2020). When incorporated in the empirical analysis, the corresponding hypothetical electricity bill is recovered by applying the percentage change to the self-reported bill. Figure 1 illustrates a choice set.[9]

[9] The choice set in Figure 1 illustrates four types of feedstocks for biomass including agricultural and forestry residues, and municipal solid waste and wastewater.

Figure 1: Example of a choice set



Source: Martínez-Cruz and Núñez (2021)

DCE implicitly frames the decision as opting in by including a status quo in the design. Hence, the hypothetical increase in bill can be interpreted as an opt-in extra fee (holding tariffs unchanged) that would compensate for an increase in the share of electricity generated with renewable energy sources —which is considered more realistic in a context where tariffs are heavily and horizontally subsidized in Mexico.[10]

[10] Historical evidence shows that residential electric subsidy in Mexico is difficult to be removed due to its high political cost. On the other hand, Hancevic and Lopez-Aguilar (2019) find that electricity consumption in the country is quite inelastic to price (-0.21) and to income (0.19). So, in the remote possibility that electric subsidy were removed, the payment of this extra fee would be affected, but not significantly.

5.2 Data collection

Face-to-face implementation of this DCE was conducted from December 11*th* to 21*st*, 2019. One thousand dwellings in Alvaro Obregon Municipality were randomly chosen through a two-stage process. A sample of electoral districts was chosen with selection probabilities based on proportional size of districts —this sample was taken using a publicly available list, provided by the National Electoral Institute. Within each sampled district, dwellings were randomly selected.

Enumerators approached potential respondents at their home and made sure that respondents were older than 18 years old and contributed to paying the household's electricity bill. Participation of respondents was not incentivized, and this may raise concerns about potential sample selection. However, potential respondents were not invited to participate on the premise that the questionnaire would explore preferences for renewable energy sources or new jobs in the renewable energy sector. Instead, respondents were invited to participate on the premise that the questionnaire explores electricity consumption patterns. In this sense, while respondents to this questionnaire may more likely be interested in electricity-related matters than non-respondents, this potential self-selection is not expected to be associated with preferences on renewable energy issues.

The questionnaire is composed of three sections. The first section presents to respondents information about renewable energy sources and what each type of renewable energy implies in terms of generation of electricity and pollution. In the second section, respondents were presented the DCE. In the third section, socioeconomic characteristics of respondents and their households are gathered.

5.3 Descriptive statistics

Once missing values have been dropped, the sample is composed of 940 respondents. Table 3 reports mean, standard deviation, minimum and maximum of variables describing respondents' and their household's characteristics. To put sample's characteristics in context, last column of Table 3 reports official statistics for household heads in the Alvaro Obregon Municipality —and, in absence of municipality-level description, Mexico City's numbers are reported (see INEGI, 2020). In comparison to official statistics of household heads in Alvaro Obregon, the sample of this study is composed by a similar share of females (55% versus 52%), and a higher proportion of married people (59% versus 39%).

Table 3: Sample's summary statistics (n=940), and official statistics for household heads in Alvaro Obregon Municipality

Variable	Mean	Std.Dev.	Min.	Max.	AAO[a]
Respondent's characteristics					
1 if respondent is female	0.553	0.497	0	1	0.524
1 if respondent is married	0.587	0.493	0	1	0.389
1 if respondent is younger than 30	0.178	0.382	0	1	0.065
1 if respondent is 30 to 40 years old	0.157	0.364	0	1	0.149
1 if respondent is 40 to 50 years old	0.191	0.394	0	1	0.212
1 if respondent is 50 to 60 years old	0.206	0.405	0	1	0.226
1 if respondent is older than 60	0.267	0.443	0	1	0.346
1 if respondent studied at least college	0.202	0.4	0	1	0.395
1 if respondent has a full-time job	0.312	0.463	0	1	0.394
Household's characteristics					
Household size	4.622	2.37	1	17	3.524
Upper-low class	0.271	0.445	0	1	—
Upper-middle class	0.188	0.391	0	1	—
Middle class	0.269	0.444	0	1	—
Lower-middle class	0.271	0.445	0	1	—
Self-reported monthly electricity bill (thousand MX pesos)	0.255	0.368	0.02	5	0.177
Inferred monthly electricity consumption (kWh)	200.4	142.153	20.949	1673	121.8

[a] Mexico City level when not available at Álvaro Obregon municipality level.

Note: A two-tailed t-test rejects at 99% the null hypothesis that the difference between sample mean and population parameter is zero – p-value is 0.0019 for a t-test statistic of 3.15.

Source: Own elaboration with information from the survey for this study and INEGI (2020).

In terms of age range, respondents of this DCE are younger than household heads in Alvaro Obregon. The proportion of respondents that are younger than 30 years old is higher in the sample (18% versus 6%). The proportion of respondents between 30 and 40 years old in the sample is almost identical to the official proportion of household heads (16% versus 15%), and a similar situation is observed for people between 40 to 50 years old (19% versus 21%), and between 50 to 60 years old (21% versus 23%). The sample in this study includes a lower share of people older than 60 years old (27% versus 35%).

In terms of education, the sample includes a lower proportion of people that has attended college at least (20% versus 39%). Also, 27% of respondents are members of household in the upper-low income class; 19%, in the upper-middle income class; 27%, in the middle-income class; and 27%, in the lower-middle class.

Finally, the number of full-time employees in the sample stands at 32 percent, compared with 39% of household heads in Alvaro Obregon. As for energy usage, the respondents self-reported 255 MXP per month as their electric bill, greater than Alvaro Obregon's 177 MXP per month. When converted to kWh, these figures result in a consumption of 200 kWh and 122 kWh, respectively.

6 Results

6.1 Estimated utility parameters

The random parameters logit (RPL) in equation (10) is estimated assuming uncorrelated normal distributions for all parameters with exception of the price parameter, which is assumed fixed.[11] Table 4 reports estimates from the random parameters logit (RPL) on six samples. When selecting the six samples, this study closely follows Martínez-Cruz and Núñez (2021) so that findings can be compared with theirs. The first specification (I) is estimated using the entire sample. The second specification (II) is estimated on a sample that includes respondents in households with eight members or less to explore whether results are driven by preferences of respondents in relatively large households —with an average of 4.62 household members, the working sample includes respondents in households with up to 17 members (see Table 3). To explore price parameter sensitivity, the third specification (III) excludes choice sets for which hypothetical bills fall below or above the 1% tails. The fourth specification is estimated on answers from respondents that pass exclusion criteria (II) and (III). The fifth specification (IV) excludes choice sets for which hypothetical bills fall below or above the 5% tails. The sixth specification is estimated on a sub-sample resulting from implementing exclusion criteria (II) and (IV).

[11] Random parameters logit reported in this work are estimated in Stata with the commands mixlogit and mixlogitwtp for the WTP-space case.

Table 4: Random Parameters Logit specifications on stated choices —assuming price parameter is fixed, and all non-price parameters are normally distributed and uncorrelated

	Entire sample	Excluding > 8 hh members	Excluding 1% tails[b]		Excluding 5% tails[b]	
	(l)	(II)	(III)	(II)+(III)	(IV)	(II)+(IV)
Mean						
Hypothetical monthly electricity bill (1000 MXP)	-5.535***	-6.073***	-8.071***	-8.637***	-12.33***	-12.67***
	(0.300)	(0.333)	(0.365)	(0.397)	(0.483)	(0.505)
1 if status quo option	-6.246***	-6.552***	-6.075***	-5.911***	-6.898***	-6.540***
	(0.449)	(0.471)	(0.438)	(0.416)	(0.537)	(0.461)
1 if solar [a]	0.348***	0.340***	0.350***	0.340***	0.336***	0.302***
	(0.051)	(0.0522)	(0.0508)	(0.0518)	(0.0533)	(0.0535)
1 if biomass [a]	-0.234***	-0.239***	-0.256***	-0.253***	-0.279***	-0.275***
	(0.0316)	(0.0329)	(0.0332)	(0.0335)	(0.0353)	(0.0356)
Hypothetical consumption of renewable energy (1000 kWh)	1.786**	1.498**	1.774**	1.702**	1.567*	1.764*
	(0.741)	(0.741)	(0.817)	(0.856)	(0.935)	(0.935)
New jobs (1000)	0.203***	0.205***	0.209***	0.206***	0.213***	0.217***
	(0.0175)	(0.0185)	(0.0184)	(0.0186)	(0.0193)	(0.0204)
SD						
1 if status quo option	4.316***	4.931***	3.958***	3.990***	-4.679***	4.170***
	(0.332)	(0.340)	(0.304)	(0.308)	(0.348)	(0.284)
1 if solar [a]	1.294***	1.267***	1.302***	1.236***	1.276***	1.233***
	(0.0531)	(0.0533)	(0.0546)	(0.0527)	(0.0558)	(0.0542)
1 if biomass [a]	-0.106	0.173**	0.247***	0.175**	0.262***	-0.203**
	(0.146)	(0.086)	(0.0714)	(0.079)	(0.0774)	(0.0842)
Hypothetical consumption of renewable energy (1000 kWh)	-5.544***	2.823	-8.144***	-8.137***	-10.36***	8.406***
	(1.452)	(3.603)	(1.572)	(1.641)	(1.439)	(1.718)
New jobs (1000)	0.214***	-0.244***	-0.249***	0.229***	0.247***	0.277***
	(0.0318)	(0.0306)	(0.0295)	(0.0328)	(0.0322)	(0.0323)
Observations	33,840	31,752	33,042	31,130	30,070	28,531
Loglikelihood	-8,902	-8,335	-8,610	-8,124	-7,742	-7,346
AIC	17,826	16,693	17,242	16,269	15,505	14,714
BIC	17,919	16,785	17,335	16,361	15,597	14,805

Standard errors in parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$.
[a] Reference category: 50/50 combination of solar and biomass.
[b] It refers to both lower and upper tails of the distribution of hypothetical monthly electricity bill.
Source: Own elaboration.

Three features in Table 4 are highlighted here. First, the price parameter is negative and significant across specifications, and its absolute value is higher when implementing exclusion criteria —which implies that responsiveness to changes in price is higher when excluding both large households and lower and upper tails of hypothetical bill. Second, point estimates of all non-monetary parameters are similar and statistically significant across specifications —i.e., changes in the composition of the sample does not seem to matter in terms of responsiveness to non-monetary attributes. Third, estimates of standard deviation of all parameters are similar and statistically significant across specifications. The first and second features are as evidence that all attributes included in this DCE are relevant to respondents; and the third feature, as evidence that unobserved heterogeneity is at place —and, consequently, RPL specifications are preferred over conditional logit specifications.

When it comes to interpreting the sign of specific parameters, the negative sign of the status quo parameter implies that respondents dislike the current conditions under which they receive electricity service. Taking solar-biomass mix as reference category, the positive sign of the solar energy parameter implies that solar is preferred over the mix; and the negative sign of the biomass parameter implies that the mix is preferred over biomass. The ordering of preferences implied by these results is consistent with previous findings documenting disutility associated with bioenergy, as it was documented in section 2.

6.2 Welfare estimates

Table 5 reports six sets of estimates of marginal willingness to pay —expressed in 2019 Mexican pesos (MXP)— for each attribute of the DCE and its 95% confidence interval. Here the study focuses on WTP estimates reported in the last column of Table 5, which arise from the specification excluding both the 5% (upper and lower) tails of the hypothetical bill and the respondents in households with more than 8 members. These estimates are relevant because they arise from the specification that yields the most responsive price parameter —and therefore, WTP estimates are conservative. Additionally, this choice facilitates comparison with Martínez-Cruz and Núñez (2021), which based their main findings on a similar sample and identical specification.

Thus, according to estimates reported in the last column of Table 5, respondents' loss in utility for remaining in the status quo situation is valued at MXP 0.516 per kWh on a monthly basis. When it comes to solar energy, respondents are willing to pay a premium of MXP 0.024 on a monthly basis for each kWh. When it comes to biomass, respondents report a negative WTP of MXP 0.022 on a monthly basis for each kWh. In contrast, biomass shows a negative WTP of MXP 0.022 per kWh per month. This result may seem surprising, given the city's significant challenges with urban waste management; one might expect a preference for adding value to waste rather than simply discarding it. Gracia et al. (2012) suggest that this low preference for biomass could stem from a lack of knowledge on sustainable biomass use and/or past negative externalities associated with its use. Similarly, Danne et al. (2021) examine interactions between renewable energy sources and their potential as feed or fuel in the German context, finding that a negative interaction term—using biogas as the reference—indicates a low willingness to pay (WTP) for sources that can double as feed. However, these explanations do not seem applicable in the context of this study.

On the bright side, this negative premium for bioenergy does not overshadow the positive WTP for one KWh of renewable energy of MXP 0.139 on a monthly basis for each kWh—regardless of its source. These numbers mean that the premium for one kWh of solar energy is equivalent to MXP (0.139 + 0.024 =) 0.163 on a monthly basis. In contrast, the premium for one kWh of bioenergy is equivalent to MXP (0.139 − 0.024 =) 0.117 on a monthly basis. As the reference category in this specifications is the 50/50 mix of renewable energies, the premium for one kWh produced with such mix is equivalent to MXP 0.139 on a monthly basis.

The marginal WTP for the creation of one new green job is MXP 0.017 on a monthly basis —or a premium of MXP 17 for 1,000 new jobs on a monthly basis. Thus, the premium for one kWh of solar energy that creates one job would be MXP (0.163 + 0.017 =) 0.180 on a monthly basis.

While these estimates of marginal WTP are informative, a policy maker would appreciate comparisons of WTP for energy contracts that include job creation because these premiums can be used in cost-benefit analyses motivating policies aiming to increase renewable energy consumption and to create jobs at the same time. These comparisons are conducted in the next section.

Table 5: Marginal willingness to pay (2019 MXP) and 95% confidence intervals resulting from Random Parameters Logit specifications reported in table 4.

	Entire sample	Excluding > 8 hh members	Excluding 1% tails[a]		Excluding 5% tails[a]	
	(l)	(II)	(III)	(II)+(III)	(IV)	(II)+(IV)
Status quo	-1.129	-1.079	-0.753	-0.684	-0.560	-0.516
Lower Bound	-1.348	-1.288	-0.888	-0.807	-0.661	-0.603
Upper Bound	-0.938	-0.897	-0.629	-0.573	-0.463	-0.434
Solar	0.063	0.056	0.043	0.039	0.027	0.024
Lower Bound	0.043	0.038	0.030	0.027	0.018	0.015
Upper Bound	0.083	0.074	0.057	0.052	0.036	0.032
Biomass	-0.042	-0.039	-0.032	-0.029	-0.023	-0.022
Lower Bound	-0.054	-0.050	-0.040	-0.037	-0.028	-0.027
Upper Bound	-0.031	-0.029	-0.024	-0.022	-0.017	-0.017
Renewable energy (kWh)	0.323	0.247	0.220	0.197	0.127	0.139
Lower Bound	0.070	0.018	0.027	0.010	-0.018	0.002
Upper Bound	0.614	0.515	0.438	0.407	0.286	0.295
One new job	0.037	0.034	0.026	0.024	0.017	0.017
Lower Bound	0.030	0.028	0.022	0.020	0.014	0.014
Upper Bound	0.044	0.041	0.031	0.029	0.021	0.021

[a] It refers to both lower and upper tails of the distribution of hypothetical monthly electricity bill.
Source: Own elaboration.

6.3 Premium for renewable energy and job creation

Table 6 reports estimates for *energy contracts* that offer not only the possibility of consuming renewable energy but bundles of energy source and creation of jobs. Thus, numbers in this table include the marginal WTP for one kWh of renewable energy. Variation in the numbers arise from combining sources (50/50 mix, biomass, or solar) and number of jobs (no jobs, 1000 jobs, or 2000 jobs). The first panel of Table 6 reports WTP for energy produced with a 50/50 mix —which is the baseline in the econometric specifications— and then reports WTP when adding 1000 jobs and 2000 jobs. The second and third panels report similar estimates but for biomass and solar energy, respectively.

The contract with the highest premium is the one that offers solar energy and creates 2000 jobs. The premium for this contract into monthly WTP —i.e., when multiplying MXP (0.333) times the sample's average consumption of 200 kWh—, it turns out that respondents' total premium is MXP 66.60 (or USD 3.46), or is 26.1% over the average price per kilowatt-hour. This proportion, at first glance, may seem too large.

Table 6: Premium for electricity generated with renewable sources and for creation of new jobs —calculated based on estimates reported in last column of table 5.

Scenarios	WTP per kWh (2019 MXP)	USD[a]	Monthly WTP (2019 MXP)	USD[a]	As proportion of self-reported bill (MXP 255)
Generated with 50/50 mix (I)	0.139	0.007	27.8	1.446	0.109
(I) + 1000 new green jobs	0.224	0.012	44.8	2.331	0.176
(I) + 2000 new green jobs	0.309	0.016	61.8	3.215	0.242
Generated with biomass (II)	0.116	0.006	23.2	1.207	0.091
(II) + 1000 new green jobs	0.201	0.01	40.2	2.092	0.158
(II) + 2000 new green jobs	0.286	0.015	57.2	2.976	0.224
Generated with solar (III)	0.163	0.008	32.6	1.696	0.128
(III) + 1000 new green jobs	0.248	0.013	49.6	2.581	0.195
(III) + 2000 new green jobs	0.333	0.017	66.6	3.465	0.261

Assuming an exchange rate of 19.22 MXP/USD which was the average closing price in 2019 (see Macrotrends, 2020).
Source: Own elaboration

Thus, let us compare the estimates to previous estimates. When it comes to WTP for one kWh, the estimated 1.7 USD cents fall well within the range of values reported in earlier studies. Ma et al. (2015), for instance, find that a majority of WTP per KWh estimates fall between -10 cent and 10 cents, and Sundt and Rehdanz (2015) report an average of 3.18 cents. When it comes to the monthly value, and the fact that it is 26% of the self-reported bill, the calculation assumes that 100% of the average consumption is covered by renewable energy. More realistically, renewable energies in CDMX initially will cover only a part of the total consumption. Taking 30% —the maximum value presented in this DCE—, the monthly WTP for solar energy that creates 2000 jobs would be MXP 20 (or just above USD 1). This number is around 8% of the self-reported monthly bill. Martínez-Cruz and Núñez (2021) have also calculated the WTP for solar energy covering 30% of consumption and creating 2000 jobs. Their estimates are equivalent to 37% of the self-reported bill. Given this benchmark, the estimates in the present study are considered to be reasonable.

7 Discussion and conclusions

This paper has illustrated that residents of the municipality Alvaro Obregon in CDMX show a high interest in renewable energy when emphasizing the creation of jobs and when the source of energy is solar. Specifically, households are willing to pay a premium if their total average electricity consumption was generated with renewable energies. If this total average consumption were produced through solar energy, residents would be willing to pay as much as almost double this first premium. However, if total average consumption were produced through biomass, residents would rather ask to be compensated for its use. In addition, residents reported to be willing to pay a monthly premium if the generation of renewable energy created one thousand jobs. The latter premium could potentially be used to compensate for the lower preference for bioenergy, which intuitively might be expected to be more preferred in large cities like CDMX due to waste management issues.

The idea that consumers may prefer certain energy sources over others is noteworthy, especially given that the electricity delivered is indistinguishable regardless of its origin. This presents a gap in the literature about the reasons behind the disutility or low preference for bioenergy. This research focuses on exploring household preferences for renewable energy and green jobs in Mexico City. While the survey offers some insights into renewable energy options, it does not offer a comprehensive evaluation of the benefits and drawbacks of each renewable source.

Solar energy, including both large-scale solar parks and distributed generation systems, benefits from relatively high public awareness. Conversely, bioenergy sources are often less recognized and are frequently associated with concerns about biomass combustion and land use, which can contribute to greenhouse gas emissions (e.g. Cherubini and Strømman, 2011). Additionally, the decreasing cost of solar panels has made them more accessible to middle- and high-income populations (Carlisle et al., 2014). In contrast, non-specialized consumers often lack detailed knowledge about the cost of bioenergy production, leading to associations with large-scale projects burdened by high transportation costs and technological inefficiencies, as noted in recent proposals for CDMX.

As a result, the potential benefits of bioenergy projects in urban areas may be underappreciated. The findings in this study suggest that middle-income residents in CDMX are likely to support policies aimed at a just energy transition, particularly those that promote the creation of green jobs.

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