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Choosing to Pay More for Electricity: An Experiment on the Level of Residential Consumer Cooperation

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Abstract: Reducing energy consumption and carbon emissions is necessary in the fight against climate change. We are interested in the situation of Quebec (Canada), where low-cost hydropower sold below market value, akin to a consumption subsidy, leads to high residential consumption. We conducted an experiment to test whether individuals would be willing to pay more for electricity. Increasing regulated prices closer to their market value would result in a direct welfare gain and free some green energy, reducing greenhouse gases (GHGs) in other sectors. Giving clear and transparent information on the consequences of the price increase induces a majority of people to choose to pay more. In addition to the economic benefit of the public good, the presence of the environmental benefit increases contributions. Participants with a more-severe budget constraint tend to contribute less. These results are encouraging for the development of efficient energy policies reducing GHG emissions.

Keywords: public good; voluntary environmental action; green electricity

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1. Introduction

Reducing CO_2 emissions in the energy sector is essential if countries are to meet their climate targets in the coming decade. Improving energy efficiency and promoting minimum energy use are two solutions to reduce energy consumption [1] and ease decarbonization efforts. However, in North America, hydro-rich regions such as the states of Washington, Oregon, Tennessee, Alabama, and New York in the United States tend to keep residential electricity prices under their market value, as hydropower is sold at cost-based energy rates [2]. In Canada, this is also true in many provinces (Ontario, British Columbia, Manitoba). These low prices encourage high electricity consumption [3,4]. It is especially the case in Quebec, which has both one of the highest hydropower production and per capita electricity consumption levels and among the lowest electricity rates [5]. Keeping prices under the market value through regulation creates a distortion and a welfare loss for society due to the unnecessary subsidization of "green" electricity. Increasing the price to the market value, and consequently reducing residential low-carbon electricity consumption in Quebec, would allow using it in other sectors and regions and would, thus, foster both energy consumption reduction in Quebec and market efficiency.

The prime interest of this paper is to investigate whether there exists a context in which people would be willing to pay more for renewable electricity. Although it seems natural that consumers would accept to pay the market price for any good, many countries have suffered a social crisis in reaction to sharp price increases, even in environmentally justifiable cases (the "Gilets jaunes" crisis in France in 2019 arose following the introduction of a carbon tax on gas). In which context are consumers from Quebec willing to pay a higher price for the same hydro-based electricity they used to pay less for? Specifically, what role is played by the environmental benefit ensuing from the consumption reduction?

It is assumed that the economic benefit stemming from the price increase materializes as greater profits for the hydro-power firm, which are then equally redistributed to all consumers. This situation relates to a public good game, where consumers decide whether they monetarily contribute to the environmental collective effort. Two laboratory experiments were conducted, one in 2009 and one in 2022, which allowed analyzing what elements affect individuals' propensity to pay a higher price for electricity.

The classic literature on public good shows that players do contribute more than what self-interest rationality predicts. Our results corroborate this observation, as we found that a majority of participants are willing to pay a higher price and that this share increased between 2009 and 2022. The presence of the environmental benefit in addition to the economic benefit seems to reinforce cooperation when the game is repeated. Initial endowment in terms of electricity consumption affects contributions: more-financially constrained households are less inclined to choose the higher price. We observed that there exists multiple cooperation behaviors when the game is repeated, but we noticed an overall tendency towards cooperation stability. This experiment, thus, demonstrates that people are willing to increase the price they are already paying for renewable electricity, in order to eliminate a welfare loss due to an unnecessary subsidy on electricity. This experiment tests in a laboratory setting if people are willing to pay more to foster economic efficiency and welfare gains, as well as to reduce GHG emissions.

Section 2 presents the literature on public good games and provides the context for this study. Section 3 presents the experimental design, and the results are provided in Section 4. A discussion follows in Section 5.

2. Literature Review

So far, the literature on multiple public good games focuses on contribution behaviors when individuals face multiple competing public goods, with identical or different returns, and have to choose what amount to contribute for each good. Ref. [6] shows that contributions increase in a multiple goods context, compared to the classic single public good game. In the case of multiple charities, framing plays a central role in the level of donations [7]. However, the literature has not covered how players react to a single public good with multiple benefits, i.e., when they make a single contribution to a public good that has several distinct outcomes, for example a financial gain and a reduction in GHG emissions.

Yet, most articles focus on abstract experimental settings, with only one public good. However, in the real-life context, many choices must be made on policies involving more than one public good. Although for some of them, there is no debate over their financing by the government (i.e., local and national security, primary education, judicial system), in other cases, this process is less obvious, and particularly for environmental protection. Despite numerous reports on the climate emergency and the various threats faced by humans, there remain controversies on how to enforce policies against climate change. Even so, there exists a substantial literature on empirical measures of the willingness to pay (WTP) for green products, and in particular for renewable electricity. A majority of estimates are derived from contingent valuation methods using responses to surveys. The controversies around this method have been extensively discussed by [8], one of them being the presence of hypothetical bias: people tend to state higher amounts from what they would actually do in reality. In that case, confirming the "true" WTP for green electricity with a laboratory experiment is of prime interest.

Many studies focus on experiments in electricity markets and mostly focus on three features: bidding schemes and market structures, psychological determinants of consumer decisions, and optimal green tariffs' contribution mechanisms. Ref. [9] uses experiments to study optimal bidding processes and market designs, while [10] argues that experiments are needed to determine optimal policies for electricity markets. Some experimental studies concentrate on the elements of the psychological environment of individuals that would influence their propensity to purchase green electricity. Ref. [11] explains that more consumers tend to choose a green tariff when it is the default option than when "gray" electricity is the default. Framing also plays a major role: when the attributes of green electricity are positively presented, people tend to select renewable energy more frequently, independently of their initial attitude towards the climate and the environment [12]. Ref. [13] discusses how the framing of electricity saving tips can affect pro-environmental intrinsic motivation and behavior. They find that environmentally framed tips have a positive short-term effect on intrinsic motivation, whereas both environmental and monetary tips increase saving intentions, but have no effect on electricity consumption. Ref. [14] studies the preference of German consumers of time-of-use (TOU) tariffs on electricity. They find that a large majority is willing to accept to pay a higher price in peak hours and reduce their demand for electricity.

The features of the chosen contribution mechanism also influence how much people are willing to pay for green electricity: Ref. [15] finds that a voluntary contribution mechanism (VCM) generates significantly more revenue than a green tariff scheme. They also find that warm-glow preferences play a central role in contribution behavior in the case of an all-or-nothing contribution mechanism. On the other hand, Ref. [16] finds that, in the context of green electricity products, consumers tend to choose the minimum level of commitment (lowest possible contribution), explained by warm-glow preferences. This result corroborates a study by [17], which finds that participation increases with environmental concern and altruistic behaviors. Moreover, Ref. [15] recommends implementing an all-or-nothing green tariff in regions where the population exhibits a high level of warm-glow altruism to maximize generated revenues. All these results confirm [18] the results mentioned above: altruism and warm-glow are intrinsically related to contribution behaviors.

The laboratory experiment presented in this paper investigates how the propensity of residential consumers to choose to pay more for electricity is influenced by an all-or-nothing contribution mechanism to a public good with multiple benefits. Consumers have heterogeneous consumption levels and face various uncertainty levels over the environmental benefit, and total contributions equally benefit all. Due to the presence of an environmental benefit that does not generate economic returns for consumers, potentially important warm-glow effects can be expected, which may lead to different results than those from the classic public good games literature. A comparison of two experiments made at a thirteen-year time interval (2009 and 2022) also allowed for a temporal comparison of contribution behaviors. Participants in 2022 played several rounds, which allowed the analysis of the group dynamics. This study is, thus, at the crossroads of different literature trends. It investigates how an experiment with a realistic price setting can help answer the following research questions: Are residential consumers willing to pay more for their electricity? How does their initial consumption affect their willingness to pay more? Does an additional environmental public good (GHG reduction) increase their propensity to contribute? Does it help to sustain cooperation over time?

3. A Public Good Game with Multiple Benefits

In this laboratory experiment, participants are endowed with heterogeneous monthly electricity consumption and are asked to choose between two prices for electricity. The basic price option reflects the current situation in Quebec (Canada), where electricity prices are low in comparison to most other North American jurisdictions, while the alternative price option (CAD 0.03/kWh higher) better reflects the price level in North America. Choosing the latter option reduces consumption, and this new surplus is sold on external markets, generating extra profits for the hydropower firm, which are then redistributed equally among all consumers. Exporting this low-cost and low-carbon electricity to external markets also creates an environmental benefit, with various degrees of uncertainty.

3.1. The Two Benefits

Electricity prices in Quebec are among the lowest in North America. For instance, in 2021, a 1000 kWh bill was CAD (Canadian Dollars) 74 in Montréal (Quebec), while it cost CAD 134 in Toronto (Ontario) and CAD 318 in Boston (Massachusetts) [19]. This is partly due to the fact that 93.6% of electricity in Quebec was produced from hydro power in 2020 [20], whose low production costs allow a low tariff based on the average-cost principle. Electricity consumption in Quebec is also the highest in Canada: in 2020, residential electricity consumption was 8266 kWh per capita in Quebec compared to a national average of 4909 kWh [3]. Low prices attract many energy-intensive industries, do not give incentives to local residential consumers to be energy efficient, and are hardly compatible with minimal energy use. On the other hand, neighboring regions charge higher prices for electricity, and it typically comes from more-polluting sources: for instance, in New England, nearly 60% of electricity is produced with natural gas [21].

When choosing the alternative price option, consumers have a higher electricity bill than with the basic price. We assumed that they consequently decrease their consumption, which liberates electricity to be exported to neighboring regions where a higher price is charged. It is assumed that increasing supply in neighboring regions does not affect market price, but this assumption is not central to our experiment and results. The publicly owned hydro-power firm, Hydro-Quebec, thus, makes higher profits from both sales. These profits are then redistributed among all local citizens, even those who chose not to contribute (those choosing the basic price option).

In addition to this economic benefit, higher electricity prices would also create an environmental benefit. It is assumed that there is no moral licensing associated with the environmental benefit, which would materialize as an increase in electricity consumption as consumers engage in a moral action by choosing to pay more. Consumers, thus, decrease their consumption when choosing the alternative price option. Exporting the hydro-power-based, and thus low-emission, electricity replaces natural-gas-generated electricity in neighboring regions, as the latter is more expensive. This would lower overall GHG emissions, which constitutes a global public good. The benefit occurs with distinct levels of uncertainty across groups. Participants do not receive any monetary compensation for the environmental benefit from their action, as is the case for most pro-environment behaviors.

3.2. Experimental Design

The experiment was first carried out at in 2009 and was then re-conducted in 2022 with some additional features. In order to allow inter-temporal comparison, all sessions were made as identical as possible. This paper examines how consumers' contribute to a public good with two benefits under heterogeneous endowment; hence, two treatments were applied to the participants. The first one is the assignment to a type of household with a given initial level of electricity consumption. Electricity consumption mostly depends on home size and whether electric heating is used or not, especially for regions enduring cold winters such as Quebec, where the experiment took place. Four types of households are defined:

- Type A, living in a single detached home and using electric heating.
  Annual consumption: **35,472 kWh** (2009), **32,054 kWh** (2022).
- Type B, living in a single detached home and not using electric heating.
  Annual consumption: **11,440 kWh** (2009), **10,338 kWh** (2022).
- Type C, living in an apartment and using electric heating.
  Annual consumption: **17,806 kWh** (2009), **16,090 kWh** (2022).
- Type D, living in an apartment and not using electric heating.
  Annual consumption: **7775 kWh** (2009), **7026 kWh** (2022).

These consumption levels were estimated first in 2009 from the Comprehensive Energy Use Database of Natural Resources Canada [22]. The consumption level of type A households was calculated identically for 2022 [23], and the same rate of change from 2009 to 2022 was applied for the other household types. As participants were initially given the same monthly budget (CAD 300), these consumption levels constitute heterogeneous initial endowments: participants with a higher initial electricity consumption are more affected by a change in electricity prices, which would decrease their disposable income more severely. It is, thus, expected that participants with a higher initial electricity consumption (such as types A and C) will be less likely to choose the alternative price option.

To control for the environmental benefit, the second treatment is the uncertainty about its materialization and, for some groups of participants, the complete absence of a benefit. Participants were facing various levels of uncertainty of GHG emission reductions when choosing the alternative price option. Three (four in 2022) levels of uncertainty were introduced:

- Certainty: Choosing the alternative price option would lead to the specified GHG emission reductions with a probability of 1.
- Risk: Choosing the alternative price option would lead to the specified GHG emission reductions with a probability of 0.5.
- Ambiguity: Choosing the alternative price option would lead to the specified GHG emission reductions with an unknown probability.
- No environmental benefit: Choosing the alternative price option would not lead to GHG emission reductions (only for the 2022 experiment sessions): no mention of the environmental benefit was made to the participants in this group.

The fourth certainty level was introduced only in 2022 and would be comparable to a classic public good game, with only one economic benefit. Table 1 summarizes the experimental design.

Table 1. Experimental design.

		Uncertainty Level about the Environmental Benefit			
		Certainty	Risk	Ambiguity	No Benefit (2022 Only)
Initial endowment	A	$\text{Group}_{A-Certain}$	Group_{A-Risk}	Group_{A-Amb}	Group_{A-NB}
	B	$\text{Group}_{B-Certain}$	Group_{B-Risk}	Group_{B-Amb}	Group_{B-NB}
	C	$\text{Group}_{C-Certain}$	Group_{C-Risk}	Group_{C-Amb}	Group_{C-NB}
	D	$\text{Group}_{D-Certain}$	Group_{D-Risk}	Group_{D-Amb}	Group_{D-NB}

3.3. The Experiment

The experiment was held twice, thirteen years apart. Both times, the sessions were held in CIRANO's Experimental Economics Laboratory in Montréal (Quebec, Canada). The sessions in 2022 repeated the 2009 sessions, but additional questions were asked in 2022. The experiment involved 200 participants in 2009 and 164 participants in 2022, where sessions in English and in French were held.

First, participants were assigned to a household type: they were asked to randomly select a card with a seat number between 1 and 20, without knowing what household type had been pre-assigned to the seat number. Each participant received an initial budget of CAD 300 for each price decision they had to make, in experimental money (the value of which was set 10-times higher than real Canadian money in 2009 and 20-times higher in 2022). In both sessions, they had to choose which price to pay for electricity from two distinct options: the basic price option and the alternative price option. Depending on their choice, they had to pay the corresponding bill from their initial budget.

In 2009, participants faced the price options presented in Table A1 in Appendix A. The basic price option (called the "current" price option at the time) represented the current residential pricing rules in place in Quebec. It included a fixed charge of CAD 12.36, independent of consumption, and a first block of 912 kWh, where each kWh was charged at CAD 0.0545, and all additional kWh were charged at CAD 0.0746. The alternative price option kept the same price structure as the basic price option, but the price per kWh increased by CAD 0.03, both in the first block and for additional kWh. This price better reflects the higher market price in neighboring regions (Ontario, New England, New York, New Brunswick) and the production costs of recent generation projects in Quebec. It is also assumed that consumers decrease their electricity consumption by 10% when choosing the alternative price option.

In 2022, participants faced the same two options. The price of the basic price option was fixed to the actual price charged by Hydro-Quebec at the time of the experiment.

The fixed charge increased to CAD 12.52; the first block increased to 1217 kWh and CAD 0.0616 per kWh; additional kWh were priced at CAD 0.095. Overall, the consumption levels of all types decreased, while the prices slightly increased: the resulting bills were equivalent in 2009 and 2022. The change of price between the basic option and the alternative option was maintained at CAD 0.03 in 2022, in order to have comparable results with the 2009 experiment and because it still reflected the difference between the price paid by consumers and the market price. The two options are presented in Table A2 in Appendix B.

Participants had one choice to make: deciding on the price and, hence, the total bill to pay between the two offered options, corresponding to the amount in the "Total" columns in Tables A1 and A2 (in Appendices A and B). The final bill depends on their assigned initial electricity consumption. As explained before, paying the higher price leads to a 10% consumption reduction, as can be seen in the tables. The power firm makes additional profits when consumers decide to pay more, since they buy 90% of the basic electricity consumption CAD 0.03 higher than before and the remaining 10% is sold on external markets, also at a price of CAD 0.03 higher. Participants were randomly placed in subgroups of four participants, with one participant of each type. The additional profits resulting from the four members' decisions were shared among them (corresponding to the social economic benefit). The final payments that each participant received amounts to the initial budget (CAD 300), minus the bill with the chosen electricity price, plus the economic benefit resulting from the group members' decisions. All payments (in real Canadian money) were rounded up to the closest multiple of CAD 5, without prior mention to the participants to prevent any effect on decisions. Table 2 shows the average profits made by the participants in round 1, depending on their household type and the price option they chose. Note that these profits also depend on the decision of other members of their group.

Table 2. Average profits (in experimental money) and standard deviations for round 1 (2022), by household type and choice of price option.

Choice of Price Option in Round 1	Household Type A	B	C	D
Basic Price Option	85.81 (1.42)	252.61 (2.91)	214.60 (2.95)	271.05 (3.28)
Alternative Price Option	58.44 (1.59)	240.68 (2.24)	202.42 (2.10)	262.69 (2.43)

To provide a real environmental outcome induced by participants' decisions, real carbon offsets were purchased at the end of the experiment, in front of the participants. The amount of offsets was equivalent to the avoided emissions resulting from the electricity consumption reductions obtained by paying the higher price. The amount of avoided emissions decreased between 2009 and 2022 (0.5 tCO_2 per 1000 kWh and 0.25 tCO_2 per 1000 kWH, respectively): coal was substituted for the less-expensive natural gas in the energy mix of Quebec's neighboring regions from 2009, which reduced pollution in these regions. The commercial website http://planetair.ca (accessed on 28 January 2024) was used to buy Gold Standard carbon offsets. The corresponding carbon offsets purchased depending on the household type are shown in Table 3 (as presented in the provided instructions).

The utility function of participant i can be specified as follows:

$$U_i = 300 - x_i - a_i(y_i - x_i) + S + a_i\beta_i(y_i - x_i) + \lambda_i \sum_N a_j(y_j - x_j)$$

$$\text{where } a_i = \begin{cases} 0 & \text{if } i \text{ chooses the basic price} \\ 1 & \text{if } i \text{ chooses the alternative price} \end{cases}$$

Table 3. GHG emission reduction and corresponding carbon offsets value for each type of participant.

2009	About 0.5 Tons of GHG Reduction per 1000 kWh Saved		Dollar Value of Carbon Offsets
	Monthly Electricity Saved (kWh)	GHG Reduction (Tons of CO_2)	
A	296	0.148	CAD 5.92
B	95	0.048	CAD 1.88
C	149	0.074	CAD 2.96
D	62	0.033	CAD 1.32
2022	**About 0.25 Tons of GHG Reduction per 1000 kWh Saved**		**Dollar Value of Carbon Offsets**
	Monthly Electricity Saved (kWh)	GHG Reduction (Tons of CO_2)	
A	267	0.067	CAD 2.54
B	86	0.022	CAD 0.82
C	134	0.034	CAD 1.27
D	59	0.015	CAD 0.56

Individual i pays the bill x_i with the basic price option and y_i with the alternative price option. The additional cost of contributing $(y_i - x_i)$ is paid when choosing the alternative price option compared to choosing the basic price option only. S represents the economic benefit each participant received from the overall contributions. This share corresponds to this calculation:

$$S = \frac{\text{Sum of basic consumption of participants choosing the alternative price} * CAD0.03}{\text{Number of participants in their subgroup (=4)}}$$

β_i ($\geq$ 0) corresponds to the warm-glow effect (or satisfaction) of the individual's own contribution $(y_i - x_i)$, and λ_i ($\geq$ 0) represents the individual sensibility with respect to the environment and altruistic preferences, i.e., the satisfaction an individual perceives from total contributions, independent of her/his own contribution.

In the case where:

$$\mathbb{E}[|y_i - x_i|] < \mathbb{E}[S + a_i\beta_i(y_i - x_i) + \lambda_i \sum_i a_i(y_i - x_i)]$$

i.e., in the case where the expected savings from not cooperating are smaller than the expected total satisfaction from cooperating, a rational player would act as an unconditional contributor (always contributes), and as a free-rider (never contributes) otherwise.

After entering the laboratory, participants were randomly given a seat number and received a set of instructions. The instructions were read out loud, and questions were answered. In the 2009 experiment, participants had only one choice to make. They took between 5 and 15 min to choose one Price option, and wrote their answer on a sheet of paper. A short exit questionnaire was distributed; carbon offsets were purchased, and payments were made.

The 2022 experiment replicated the 2009 experiment, with the exception that it was held using the *Z-tree* software (version 5.1.6) [24], and additional questions were asked. After learning about their type and being randomly placed in a group of four participants, they were asked questions about their conditional contribution preferences, depending on how many members in their group chose the alternative price option. Questions were asked as follows: Which option do you choose in the following situation?

- Three participants in your group choose the basic price option.
- Two participants choose the basic price option, and one participant chooses the alternative price option.

Such questions were asked for all possible combinations of contributing and non-contributing members. These questions allowed deducting the types of contributors (free-rider, conditional contributor, or unconditional contributor). They did not receive any payments based on these questions. Then, they executed three rounds on their unconditional contribution preferences: they were asked to choose one price option, as in the 2009 experiment, without knowing what option was chosen by other participants in their group. The number of participants in the group of four who chose the alternative price option in this round was disclosed to each participant, as well as the resulting economic and environmental benefits. The first round replicated the 2009 experiment. For the second round, they remained in the same group of four participants, received another CAD 300, and were asked to choose between the two options, knowing how many participants chose to contribute in the previous round. Again, the resulting economic and environmental benefits were disclosed, along with the number of participants in their group who chose to contribute. In the third round, the groups were randomly shuffled, and each participant was placed in a new group of four participants. They had a new CAD 300 budget and had to choose between the two options, and the results were displayed. They received a payment for their answers in these three rounds. Finally, they had to fill in exit questionnaires measuring their altruistic behaviors, their sensibility with respect to the environment, and their level of confidence in the institutions. These questionnaires were conceived after [17] and after the Eurobarometer and Latinobarometer and were not included in the participants' payments. The questionnaire on the sensibility with respect to the environment followed the statements developed in the New Ecological Paradigm [25], while the one on altruistic preferences adopted statements established by [26,27]. The questions asked can be found in Table 4, as well internal consistency for each scale, measured by Cronbach's alpha (Altruism and sensibility with respect to the environment were measured with a five-point scale, ranging from "strongly agree" to "strongly disagree", whereas the trust in institutions scale ranged from "very high" to "not high at all". Answers were then re-coded from 1 to 5 to translate preferences, where high numbers represent a high sensibility with respect to the environment, strong altruistic preferences, and high levels of confidence in the institutions).

In both 2009 and 2022, the various uncertainty groups received slightly distinct instructions on the environmental benefit realization:

- Risk group: "There may be an environmental benefit from choosing the alternative option. To determine whether there is an environmental benefit, we will place 10 balls in a bag, 5 blue, and 5 yellow. At the end of the experiment, one participant will choose the color that represents the benefit, and another participant will pull a ball out of the bag without looking into the bag. If the ball is the color representing the benefit, then there is a benefit. If the ball is not the color representing the benefit, then there is no benefit."
- Ambiguity group: "There may be an environmental benefit from choosing the alternative option. To determine whether there is an environmental benefit, we will place 10 balls in a bag, an unknown number of blue, and the rest yellow. At the end of the experiment, one participant will choose the color that represents the benefit, and another participant will pull a ball out of the bag without looking into the bag. If the ball is the color representing the benefit, then there is a benefit. If the ball is not the color representing the benefit, then there is no benefit."

Participants in the certainty group were told that the environmental benefits shown in Table 3 would happen as a consequence of all participants' decisions. In 2022, no mention of an environmental benefit was made to the no benefit group.

It was expected that more participants would choose the alternative price option in 2022, compared to the 2009 sessions, as the environment, climate change, and energy issues have been more extensively discussed in the public sphere and might have motivated participants to contribute more. Considering the findings in the classic experimental literature, participants with a low endowment (a high initial electricity consumption: types A and C) and/or facing uncertainty in the environmental benefit should be contributing less than other participants. One also expects that the number of participants choosing the alternative price option will decrease when the choice is repeated. A lower decrease than what the classic theory predicts might be observed, as more unconditional contributors can be expected due to the presence of the environmental benefit.

Table 4. Questions in the exit questionnaire.

	Questions	Mean	Standard Deviation
	Altruism Scale		
	Five-point scale, from "strongly disagree" (1) to "strongly agree" (5)		
1.	Contributions to community organizations rarely improve the lives of others.	3.74	0.10
2.	The individual is responsible for his or her well-being in life.	2.95	0.10
3.	It is my duty to help other people when they are unable to help themselves.	3.59	0.08
4.	My responsibility is to provide only for my family and myself.	3.52	0.09
5.	My personal actions can greatly improve the well-being of people I don't know.	4.23	0.07
	Final score	18.02	0.30
	Cronbach's alpha	0.6824	
	NEP Scale		
	Five-point scale, from "strongly disagree" (1) to "strongly agree" (5)		
1.	Plants and animal have as much rights as humans to exist.	4.42	0.07
2.	The so-called "ecological-crisis" facing humankind has been greatly exaggerated.	4.35	0.07
3.	Human ingenuity will ensure that we do not make the earth unlivable.	3.20	0.09
4.	The earth is like a spaceship with very limited room and resources.	4.04	0.09
5.	The balance of nature is strong enough to cope with the impacts of modern industrial nations	4.08	0.09
	Final score	20.09	0.23
	Cronbach's alpha	0.4652	
	Institutional Trust		
	Five-point scale, from "not high at all" (1) to "very high" (5)		
1.	Provincial government	2.68	0.08
2.	Federal government	3.07	0.08
3.	Public administration	2.81	0.07
4.	Social benefit system	3.07	0.08
5.	Hydro-Québec	3.01	0.09
	Final score	14.64	0.29
	Cronbach's alpha	0.7867	

4. Results

In the following section, a cooperator is defined as a participant who chooses the alternative price option or, equivalently, who chooses to contribute. Table 5 summarizes unconditional contributions in the 2009 experiment and in the 2022 experiment (the single question in 2009 and the three rounds in 2022), by type of household and by certainty level about the environmental benefit. Variations coming from different sources were analyzed: between-sessions (2009 and 2022), between-subjects (types of households), between-treatments (levels of uncertainty), and between-periods (three rounds in 2022).

Are participants willing to pay more?

Overall, contributions increased substantially between 2009 and 2022 (respectively, 52% and 59.15%). In particular, if only the certainty, risk, and ambiguity groups are considered in 2022 for a more-accurate comparison, the share of cooperators in the first round increased by nearly 11 percentage points between 2009 and 2022. The one-sample t-test showed that this difference was significant (the p-value was 0.0084) (all the tests performed in this section are summarized in Appendix C). Several factors can explain this difference, as explained in the following sections.

Table 5. Results of the experiment: proportion of participants choosing to contribute.

Year	Round	Type				Certainty Level			No Benefit	Total
		A	B	C	D	Certainty	Risk	Ambiguity		
2009	1	44.00%	54.00%	56.00%	54.00%	56.25%	57.35%	42.65%	-	**52.00%**
2022	1	47.83%	59.52 %	67.50%	63.89 %	55.26%	64.44%	69.70%	50.00%	**59.15%**
						62.93% (Certainty, Risk, Ambiguity combined)				
	2	36.96%	59.52%	62.50%	63.89%	57.89%	62.22%	66.67%	37.50%	**54.88%**
	3	41.30%	50.00%	55.00%	61.11%	57.89%	57.78%	57.56%	35.42%	**51.22%**

Does initial endowment affect the willingness to pay?

It can be expected that contributions vary among households types, since it is more costly for participants endowed with a higher initial electricity consumption (namely types A and C) to choose the alternative price option. χ^2 tests were performed at a confidence level $\alpha = 5\%$, and the hypothesis of independence between all types of household and contribution could only be rejected for the second round in 2022 (p-values were, respectively, 0.62 for 2009; 0.269, 0.038, and 0.324 for the three rounds in 2022). Also, type A households were more financially constrained than any other type. The share of type A participants who chose the alternative option was compared with the share of participants that were not a type A household and chose the alternative option in all rounds. This difference was tested at a confidence level $\alpha = 5\%$. In 2009, it could not be concluded that a lower proportion of type A participants chose to pay more compared to other types (the p-value was 0.126), but the null hypothesis was rejected in 2022 for all rounds at a 10% confidence level (the p-values were 0.0331, 0.0019, and 0.0571, respectively, for the three rounds), meaning that a lower share of type A participants contributed compared to other types of household.

Does the environmental benefit increase the propensity to contribute?

The results were as expected, but slightly different in 2009 and 2022. Ambiguity about the environmental benefit reduced cooperation in 2009, but not in 2022. However, the absence of the environmental benefit significantly reduced cooperation in 2022. Certainty did not play the same role in 2022 as in 2009, and no definitive explanation could be found for this. Maybe, the understanding of the probabilities played a role or the explanation of the uncertainty level got caught up in the flow of information given in the instructions.

The certainty level (certainty, risk, ambiguity, and absence of benefit) and contribution were not independent only in the second and third rounds in 2022, at a 10% confidence level (the p-values were 0.16, 0.268, 0.032, 0.079, respectively).

In 2009, participants in the ambiguity group contributed significantly less than participants in the two other groups (the p-value was 0.04).

For the three rounds in 2022, the share of cooperators in the groups that faced an environmental benefit (namely the certainty, risk, and ambiguity groups combined) were compared with the share of cooperators in the group with no environmental benefit. There was no significant difference in the scores for the altruism scale, the NEP scale, and the institutional trust scale between these two groups (the p-values were, respectively, 0.9293, 0.6665, and 0.2404). The groups with an environmental benefit contributed proportionally more in all rounds, at a 10% confidence level (p-values of 0.0634, 0.0019, and 0.0045, respectively).

How does cooperation evolve over time?

As several rounds were played in 2022, the dynamics of the contributions can be analyzed. Between the first and second rounds, most participants did not change their behavior: they kept choosing the alternative option or they kept choosing the basic option. Table 6 shows the contribution behavior changes between the first and the second rounds, depending on the number of participants that chose the alternative price option in the first round.

Table 6. Change in contributions between round 1 and round 2, by number of contributors in the group in round 1.

Contributions in Round 2	Number of Contributors in Round 1					
	0	**1**	**2**	**3**	**4**	**Total**
Started contributing	3	2	10	5	-	20
Share among those starting	15%	10%	50%	25%	-	12.20%
Stopped contributing	-	6	12	5	4	27
Share among those stopping	-	22.22%	44.44%	18.52%	14.81%	16.46%
Continued contributing	-	3	24	31	12	70
Share among those continuing	-	4.29%	34.29%	44.29%	17.14%	42.98%
Continued not contributing	6	13	23	5	-	47
Share among those not continuing	12.77%	27.66%	48.94%	10.64%	-	28.66%
Total	9	24	69	46	16	164
	5.49%	14.63%	42.07%	28.05%	9.76%	

It was expected that some participants would change their behavior in the second round depending on what the other members in their group did in the first round, especially since the group composition did not change between these two rounds. Overall, participants who started contributing in the second round were in groups with not many members contributing in the first round, while participants who stopped contributing in the second round were in groups with a majority of members contributing in the first round. These behaviors can be interpreted as a desire for stability in the total level of contributions (which can be defined as a behavior of a triangle contributor). Incidentally, contributions slightly decreased between the first and second rounds.

The same observation was made for changes in behavior between the first round and the third round. The groups were randomly shuffled between the second and third rounds, meaning that participants had no prior knowledge about the contribution behaviors of the new group members, but they may have had expectations depending on what happened in their group in the first two rounds. For instance, a decreasing number of participants between the first and the second round might have induced deception, thus encouraging a participant who contributed in the first round to stop contributing in the third round, although no knowledge about the new members' propensity to contribute was available. The vast majority of participants did not change their behavior in the third round compared to the first round. Table 7 summarizes the changes in behaviors between the first and the third rounds.

Table 7. Change in contributions between round 3 and round 1, by the difference in the number of contributors between round 1 and round 2.

Contributions in Round 3	Difference in the Number of Contributors				
	−1	**0**	**1**	**2**	**Total**
Started contributing	6	9	0	0	15
Share among those starting	40.00%	60.00%	0%	0%	9.15%
Stopped contributing	2	9	10	7	28
Share among those stopping	7.14%	32.14%	35.71%	25.00%	17.07%
Continued contributing	17	37	14	1	69
Share among those continuing	24.64%	53.62%	20.29%	1.45%	42.07%
Continued not contributing	14	28	8	4	52
Share among those not continuing	26.92%	53.85%	15.38%	7.69%	31.71%
Total	39	83	32	12	164
	23.78%	50.61%	19.51%	7.32%	

Again, participants who started contributing were in groups where cooperation declined or remained constant between the first and second round, while the majority of participants who stopped contributing were in groups where cooperation generally increased between the first two rounds.

Does the environmental benefit help sustain cooperation over time?

Table 5 shows that cooperation dropped by 15 percentage points in the third round among participants who did not face the environmental benefit, compared to less than 5 percentage points when the environmental benefit was mentioned. To test whether the presence of the environmental benefit helped maintain a stable number of contributors over time, it was tested whether the difference in the share of cooperators between rounds 1 and 3 in the no-benefit group was greater than in the groups facing the environmental benefit. The presence of the environmental benefit did not significantly help sustain cooperation over time (the *p*-value was 0.1406). However, cooperation in the group facing the environment benefit *with certainty* tended to be more stable than in all other groups (the *p*-value was 0.0719). Guaranteeing that paying a higher price for electricity will lead to GHG emission reductions thus allowed maintaining the number of contributors when repeating the game.

Does the environmental benefit affect conditional cooperation?

The 2022 experiment included additional questions on conditional contributions, where participants had to decide what price option to pay depending on the number of members in their group who chose the alternative price option (see Section 3.3 for more details). This allowed defining three types of contributors:

- The free-riders: they never chose the alternative price option, for any number of participants in their group choosing the alternative price option.
- The unconditional contributors: they chose the alternative price option, for any number of participants in their group choosing the alternative price option.
- The conditional contributors: they cooperated only if other members of their group cooperated (the minimum required number of cooperators varied across participants).
- Contribution behaviors that do not exhibit a logic that falls into the types defined above were considered as "others".

Table 8 summarizes the proportion of participants choosing the alternative price option in the preliminary questions, depending on the presence of the environmental benefit. As can be expected, the number of cooperators increased with the number of participants contributing in the group. Also, there were more cooperators in the groups with an environmental benefit than without, but this difference was not significant for most questions (the *p*-values were 0.2244, 0.0119, 0.7274, and 0.1609, respectively). Table 9 shows the types of contributors by type of household. There were significantly more free-riders in proportion among the type A households (the *p*-value was 0.0012), as well as significantly less unconditional contributors (the *p*-value was 0.0162). This confirmed the hypothesis that the more financially constrained participants were, the less likely they were to contribute. Also, note that, among all the participants, there was proportionally more unconditional contributors than free-riders.

Table 8. Share of contributors in conditional contribution questions.

	Environmental Benefit		
	With	**Without**	**Total**
if 0 contributor	35.34%	29.17%	33.54%
if 1 contributor	56.90%	37.5%	51.21%
if 2 contributors	59.48%	64.58%	60.98%
if 3 contributors	72.41%	64.58%	70.12%
N	116	48	164

Table 9. Type of contributor, by type of household.

	Sum	Share
Type A	46	28.05%
Unconditional Contributors	5	10.87%
Free-Riders	14	30.43%
Conditional Contributors	21	45.65%
Others	6	13.04%
Type B	42	25.61 %
Unconditional Contributors	10	23.81%
Free-Riders	5	11.90%
Conditional Contributors	14	33.33%
Others	13	30.95%
Type C	40	24.39%
Unconditional Contributors	11	27.5%
Free-Riders	2	5%
Conditional Contributors	20	50%
Others	7	17.5%
Type D	36	21.95%
Unconditional Contributors	10	27.78%
Free-Riders	6	16.67%
Conditional Contributors	12	33.33%
Others	8	22.22%
Total		
Unconditional Contributors	36	21.95%
Free-Riders	27	16.46%
Conditional Contributors	67	40.85%
Others	34	20.73%
N	164	

The contributions to the following rounds showed that some contributors were irrational, i.e., they did not follow the contribution behavior that was associated with their type. For instance, some participants that were defined as free-riders from their answers in the preliminary questions (they never contributed, whatever the number of other cooperators) chose the alternative price option in one of the three unconditional contribution rounds. Table 10 summarizes irrational behaviors (the number of times a participant defined as a free-rider contributed and a participant defined as an unconditional contributor did not contribute) and irrational contributors (some participants were irrational in several rounds, meaning that there were fewer irrational participants than irrational behaviors). No real tendency could be determined in the reasons behind these changes of behaviors.

Table 10. Irrational behaviors.

Rounds	Irrational Unconditional Contributors	Irrational Free-Riders	Total	Total
Round 1	1	0	1	0.61%
Round 2	5	5	10	6.10%
Round 3	9	4	13	7.93%
Irrational behaviors	15	9	24	4.88%
Irrational participants	10	6	16	9.76%

Do individual characteristics affect cooperation?

The 2022 experiment included a questionnaire to evaluate the participants' altruistic preferences, their sensibility with respect to the environment, and their confidence in the institutions. All these factors can potentially affect the propensity to choose to pay more for electricity. The independence of the score for environmental sensibility and contributions and the score for institutional trust and contributions in all rounds cannot be rejected, at a 5% confidence level. It seems that contributions are not determined by the score a participant gets on these questionnaires. However, the hypothesis of independence between altruism and contributions can be rejected in rounds 2 and 3. It seems that altruistic preferences play a role in sustaining cooperation, but are not necessary to create cooperation in the first place.

Summary

It can be concluded that households with a higher electricity consumption (type A), i.e., households with a more-severe budget constraint, tended to choose to pay more in a lower proportion than the other types of consumers for whom it was less costly to choose the higher price. This conclusion holds for all years of the experiment. Besides, the environmental benefit played a role in the choice of paying more: in 2009, participants facing a higher degree of uncertainty about the realization of the benefit tended to contribute less. This observation did not hold in 2022, but participants for which the environmental benefit was not mentioned chose the alternative price proportionally less than participants who faced a potential (certain or not) environmental benefit. Furthermore, it seems that the environmental benefit helped sustain cooperation over time as the share of cooperators decreased more rapidly in the no-benefit group. Certainty about the realization of the environmental benefit seems to be a better vector of persistent cooperation. The dynamics in the 2022 experiment revealed that a variety of individual behaviors existed. Depending on the expectations that were formed in the first round, once participants had knowledge of their fellow group members' cooperation behaviors, some participants adapted their decision, even in the third round when they were joined with new unknown group members. If overall contributions steadily decline through the rounds, there seems to be a desire for cooperation stability, as a significant number of participants still started to contribute in later rounds.

5. Discussion

The experiment allowed answering the initial research questions: Are a majority of participants willing to pay more for electricity in the Quebec context investigated here? This is encouraged by the two benefits of the public good: the economic benefit, where total contributions are equally shared among all participants, even those who did not contribute, and the environmental benefit resulting from the export of the saved green electricity to neighboring regions where electricity comes from more-polluting sources. A few other interesting results can be highlighted. The initial conditions of people matter: participants with a higher electricity consumption cooperate significantly less than participants with a less-severe budget constraint. The environmental benefit plays a notable role in the choice to pay more: contributions significantly increased between 2009 and 2022, and as the financial incentives were kept equal, it was assumed that the difference might be explained by the growing environmental concern in a thirteen years' time. Also, participants in groups facing a higher certainty level about the realization of the environmental benefit contributed more than others in 2009, and participants facing any strictly positive probability of realization about the benefit contributed more than participants facing no environmental benefit at all. Accordingly, contribution behaviors are influenced by the presence of the environmental benefit, as suggested by previous findings [17,18]. This also confirms the results of [13] that environmental and social considerations affect consumers' electricity saving intentions.

These results confirm that there exists conditions in which people are willing to pay a higher price for their consumption of energy. In the case of Quebec, consumers already consume "green" electricity, but at a price kept artificially low, which induces high electricity consumption. This allows governments to seize the opportunity to increase the price for goods and services for which a lower consumption would benefit society. However, this situation relies on specific conditions: it is essential to give clear and transparent information on the exact consequences of the price increase, especially on the environment.

This experiment relied on specific assumptions. Here, all participants were financially able to pay the higher price: households that did not have the means to pay more were not accounted for. A very basic framework for the distribution of total contributions was developed, where all participants received an equal share of total contributions. Other approaches could be imagined: for instance, contributions could be transferred to a fund for low-income households or to a fund only for consumers who choose the higher price to support them in their energy transition. Such policies might increase cooperation even more. It was also assumed that all participants would decrease their consumption by 10%, although in reality, the reduction of consumption in response to a higher electricity price depends on many factors: whether the consumer owns or rents her/his dwelling, the quantity that is already consumed, etc.

Some elements of this experiment might overestimate the final results. Participants voluntarily took part in this experiment, and there might be a self-selection bias, as they might have been initially more curious about energy consumption. It was noticed that a significant share of participants were students, who might exhibit lower levels of aversion to tight budgets. Although the level of education, gender, and socio-cultural background were not controlled for, a great diversity in ages, social backgrounds, and occupations was observed, but it cannot be determined whether these factors might affect the results, and in what direction. Also, the decision to pay more is not based on a long-term commitment: it concerns a limited engagement, with no lasting significance. It could be expected that answers in this experiment tended to overestimate the number of consumers who would actually choose to pay more if their decision were to commit them for a long-term contract, and also if they were to sustain a (often costly) long-term 10% consumption reduction.

6. Conclusions

The literature on public goods has so far focused on experimental settings with one public good, while in the electricity sector, studies focus on market design. Some experiments focused on green electricity programs and how contribution mechanisms and warm-glow affect the choice of paying more. This paper explores multiple aspects of electricity consumption: when and how are consumers willing to pay more, especially when they already consume renewable, yet heavily subsidized electricity and when an environmental benefit is introduced, and how the initial endowment of consumers affects cooperation. The results reported are very encouraging for future policy designs: the voluntary decision to pay more for electricity was observed when economic and environmental returns were presented in a clear and transparent manner to participants, even in the presence of uncertainty. In particular, the presence of the environmental benefit significantly encouraged cooperation. Future research could focus on what features of the program design could increase cooperation even more: the redistribution of total contributions, what information from participants' decisions is publicly revealed, and so on. This could help design efficient energy policies to decrease GHG emissions and meet climate goals.

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Appendix A

Table A1. Price options in 2009.

	Basic Price Option Specification				
	Monthly Consumption (kWh)	Fixed Charge CAD 12.36	Price of First 912 kWh CAD 0.0545	Price of Additional kWh CAD 0.0746	Total
A	2956	CAD 12.36	CAD 49.73	CAD 152.45	CAD 214.54
B	953	CAD 12.36	CAD 49.73	CAD 3.05	CAD 65.14
C	1484	CAD 12.36	CAD 49.73	CAD 42.62	CAD 104.71
D	645	CAD 12.36	CAD 35.31	CAD 0.00	CAD 35.31
	Alternative Price Option Specification				
	Monthly Consumption (kWh)	Fixed Charge CAD 12.36	Price of First 912 kWh CAD 0.0845	Price of Additional kWh CAD 0.1046	Total
A	2660	CAD 12.36	CAD 77.11	CAD 182.83	CAD 272.30
B	858	CAD 12.36	CAD 72.50	CAD 0.00	CAD 84.86
C	1335	CAD 12.36	CAD 77.11	CAD 44.24	CAD 133.71
D	583	CAD 12.36	CAD 49.27	CAD 0.00	CAD 61.64

Appendix B

Table A2. Price options in 2022.

	Basic Price Option Specification				
	Monthly Consumption (kWh)	Fixed Charge CAD 12.52	Price of first 1217 kWh CAD 0.0616	Price of Additional kWh CAD 0.095	Total
A	2671	CAD 12.52	CAD 74.93	CAD 138.21	CAD 225.66
B	861	CAD 12.52	CAD 53.06	CAD 0.00	CAD 65.58
C	1341	CAD 12.52	CAD 74.93	CAD 11.80	CAD 99.26
D	585	CAD 12.52	CAD 36.06	CAD 0.00	CAD 48.58
	Alternative Price Option Specification				
	Monthly Consumption (kWh)	Fixed Charge CAD 12.52	Price of First 1217 kWh CAD 0.0916	Price of Additional kWh CAD 0.125	Total
A	2404	CAD 12.52	CAD 111.43	CAD 148.45	CAD 272.40
B	775	CAD 12.52	CAD 71.01	CAD 0.00	CAD 83.53
C	1207	CAD 12.52	CAD 110.53	CAD 0.00	CAD 123.05
D	527	CAD 12.52	CAD 48.26	CAD 0.00	CAD 60.78

Appendix C

Table A3. Tests.

Chi-Squared Tests			
Test variables	Chi-squared	*p*-value	Rejected/ not rejected
Contribution R1 and type	3.9323	0.269	Not rejected
Contribution R2 and type	8.4515	0.038	Rejected
Contribution R3 and type	3.4736	0.324	Not rejected
Contribution R1 and altruism	15.3008	0.503	Not rejected
Contribution R1 and NEP	12.3595	0.577	Not rejected
Contribution R1 and confidence	23.7730	0.163	Not rejected
Contribution R2 and altruism	25.1833	0.067	Rejected
Contribution R2 and NEP	10.4653	0.727	Not rejected
Contribution R2 and confidence	23.9496	0.157	Not rejected

Table A3. *Cont.*

Chi-Squared Tests			
Contribution R3 and altruism	31.7958	0.011	Rejected
Contribution R3 and NEP	13.6837	0.474	Not rejected
Contribution R3 and confidence	16.5595	0.554	Not rejected
***t*-Tests**			
Hypothesis	t-stat	*p*-value	Rejected/ not rejected
H_0: $\Pi_{EB-2022} = 0.52$ vs. H_a: $\Pi_{EB-2022} > 0.52$	1.8561	0.0326	Rejected
Contribution R1: H_0: $\Pi_A = \Pi_{\overline{A}}$ vs. H_a: $\Pi_A < \Pi_{\overline{A}}$	1.8493	0.0331	Rejected
Contribution R2: H_0: $\Pi_A = \Pi_{\overline{A}}$ vs. H_a: $\Pi_A < \Pi_{\overline{A}}$	2.9373	0.0019	Rejected
Contribution R3: H_0: $\Pi_A = \Pi_{\overline{A}}$ vs. H_a: $\Pi_A < \Pi_{\overline{A}}$	1.5886	0.0571	Rejected
Altruism: H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} \neq \Pi_{\overline{EB}}$	0.0823	0.9345	Not rejected
NEP: H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} \neq \Pi_{\overline{EB}}$	−0.1767	0.8600	Not rejected
Confidence: H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} \neq \Pi_{\overline{EB}}$	−1.1305	0.2599	Not rejected
Contribution R1: H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} > \Pi_{\overline{EB}}$	−1.5344	0.0634	Rejected
Contribution R2: H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} > \Pi_{\overline{EB}}$	−2.9343	0.0019	Rejected
Contribution R3: H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} > \Pi_{\overline{EB}}$	−2.6437	0.0045	Rejected
Difference in contributions between R1 and R3			
H_0: $\Pi_{EB} = \Pi_{\overline{EB}}$ vs. H_a: $\Pi_{EB} < \Pi_{\overline{EB}}$	−1.0812	0.1406	Not rejected
Free-riders: H_0: $\Pi_A = \Pi_{\overline{A}}$ vs. H_a: $\Pi_A > \Pi_{\overline{A}}$	−3.0803	0.0012	Rejected
Uncond. contributors: H_0: $\Pi_A = \Pi_{\overline{A}}$ vs. H_a: $\Pi_A < \Pi_{\overline{A}}$	2.1580	0.0162	Rejected

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