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A green, connected future Britain: Would you share your energy to protect your local hospital during an energy crisis?

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Accepted for publication in Energy Research & Social Science

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Abstract

Future renewable energy-reliant smart grids may not be able to guarantee supply to meet demand. This could result in loss of power to essential services, such as hospitals. Households with electric vehicles and battery storage may collectively provide an emergency energy resource in this context. This study examined how householders might behave if asked to share their stored energy. Specifically, we examined if willingness to share is influenced by: level of monetary incentives relative to donation; amount of power householders have stored; urban or rural location. Householders in England (n=1051) participated in 3 randomised online vignette-based experiments. Monetary incentive and resource scarcity were manipulated and their interaction with geographical location (urban/rural) and incentive framing ('give'/'sell') examined. The dependent variable was number of hours' stored electric vehicle battery energy shared with a local hospital. Findings showed that householders shared equivalent hours of energy when asked to donate, sell at no loss, or at a profit. However, participants shared far less at a loss relative to all other conditions. In regard to stored energy available (1, 3 or 5 days' energy) ~84% participants shared at least some energy and those with more supply gave more, though proportionately less. Urban vs. rural and give vs. sell conditions were non-significant. Findings suggest householders would donate energy to essential services as a part of energy crisis management, even if their own energy resource is scarce. Importantly, compensation is unnecessary, because covering costs or allowing profit is no more effective than asking for a donation.

Keywords: renewable; energy security; environmental psychology; prosumer; resource scarcity; sustainability

1 Introduction

The UK Government has set a binding target to achieve net zero emissions by 2050 and a policy of decarbonising the UK's power system by 2035 [1]. A central aspect of meeting decarbonising targets is household energy use. This is because householders contribute substantially to UK emissions [2] and everyday energy decisions are influenced by complex social, psychological and structural factors [3]. Consequently, important innovations in the supply of renewable energy sources, such as wind or solar-derived power, will need to be matched by similarly innovative demand-side flexibility and society's willingness to engage with these. This will involve changes to energy use patterns, energy storage and the technologies to help manage these.

Critical to the successful implementation of demand-side flexibility innovations is the effective integration of individual and community needs. Brooks and colleagues [4] showed that such integration is fundamentally social. They conducted a UK community-energy simulation study which demonstrated that householders' willingness to coordinate their energy use collectively played a key role in successfully managing energy demand. However, renewable energy sources are intermittent meaning that energy may not be readily available to meet everyone's needs at a given time and would need to be allocated based on priority, for example, essential services. It is therefore important to be able to anticipate how households might behave in this context and to mitigate potential risks to both households and the communities they live in. The primary aim of the study is to provide novel insight into how households might behave in a future energy-scarce context.

Considering general evidence on sharing behaviour, a broad range of motivations have been identified, such as altruism, utility, economy, social-hedonism and/or morality [5, 6]. It seems likely that these motivations may underly energy sharing in a crisis, but this has not been directly tested. Likewise, given that people are willing to share their monetary [7] and non-monetary resources [8], even when these are limited [9], they may behave similarly in an energy crisis context.

Energy sharing and gifting is a relatively new concept given that energy has, until recently, been exclusively provided by large-scale energy companies. Even so, energy-based research and industry initiatives shows that the UK is approaching technical readiness to move towards community-based energy sharing as exemplified by initiatives such as ‘Energy Local’ through which local energy sharing is already being trialled and adopted. Energy Local is a cooperative model which creates community-run “Energy Local Clubs” where households match their electricity use to nearby renewable generators and pay a locally agreed tariff, lowering consumer bills while ensuring generators receive a fairer price for their output. Alongside these initiatives, Brooks and colleagues [4] used data from the UK Household Electricity survey to model ‘social’ relative to ‘selfish’ strategies to improve demand-side energy management. They showed that the latter was more effective at trading time-slots with other agents contingent on communities being small, with diverse households e.g. a mix of pensioners and non-pensioners and that the structure of cooperation (reciprocation) was maintained. Moreover, qualitative studies with prosumers and consumers, for example, Pumphrey and colleagues [10], provide recommendations for peer-to-peer energy trading systems based on interviews which address concerns regarding ease of use, trust, transparency regarding community benefits and pricing structures. There is also evidence of social readiness where, for example, Georgarakis and colleagues [11]'s experimental work with prosumer householders in the Netherlands demonstrated that pro-social motivations are evident in peer-to-peer energy trading. Congruently, a choice experiment with potential and current prosumers in Switzerland provide experimental evidence that households are willing to be flexible [12]. However, the willingness to be flexible depended on how tangible the inconvenience was. For instance, heat pump owners for whom flexibility was defined by physical comfort were less willing than electric vehicle (EV) and photovoltaic groups. Even EV owners who were the most flexible of the three showed a sharp drop in flexibility when the battery charge fell below 60%. This prior research assumes normal availability of energy. However, energy sharing in a crisis situation has not been previously considered. It is therefore timely to examine how UK residents would respond in such a situation, where social motivation might be critical. With this in mind, our study sought to evaluate how people behave when they are forced to balance their household's needs against their community's needs in an emergency.

We hypothesized that three factors are likely to drive sharing behaviour: settlement type, monetary incentive and householders' current energy availability. Critically, we investigated the effect of these factors in the context of restricted availability where all householders and essential community services they rely on, such as a hospital, are subject to an unexpected and potentially lengthy power outage. Within this context, we had three research questions. Is willingness to share influenced by: (1) level of monetary incentives relative to donation?; (2) amount of power householders currently have access to?; (3) urban relative to rural location?

1.1 Monetary incentives vs. donations

Monetary incentive research consistently shows that people respond positively to tokens of appreciation, whether monetary or non-monetary in nature [13, 14]. Even nominal monetary incentives seems sufficient to drive a willingness to share [for review see 15]. Such effects are likely relevant in an energy sharing context. For instance, Pumphrey and colleagues [10]'s interviews revealed that UK energy consumers and prosumers emphasized cost, cheap tariffs and economic return as primary drivers for their energy decisions. In addition, evidence shows that prosumers are willing to engage in flexible energy use practices provided that there is some economic incentive [12]. The same has been found regarding switching to renewables [16]. While themes around cost and financial rewards are well-established, no studies have empirically tested the impact of monetary incentives relative to donations on willingness to share energy, although, donation and solidarity-based energy-sharing models are beginning to emerge [17, 18]. Drawing on broader research on donating behaviour, perceived vulnerability has been shown to drive people to be more generous [19]. Furthermore, when people perceive themselves as physically vulnerable, they are more likely to give and to give more generously [20]. In a series of experiments, Motsenok et al. [20] showed that when vulnerability was made salient or when participants perceived themselves as physically vulnerable, they were more generous than the non-vulnerable group, likely driven by an other-oriented emotional response e.g. sympathy or compassion (ibid). This other-focused orientation as the underlying mechanism of prosocial behaviour is further supported by fMRI evidence [21]. Energy-related donating also demonstrates pro-social tendencies. In an online study of energy prosumers, Georgarakis and colleagues [11] used a survey and experiment to demonstrate that more than half of their respondents were willing to donate surplus energy while three quarters were willing to accept an indirect return. This evidence is based on normal operating conditions, however. Our review of literature suggests that both monetary incentives and prosocial orientations may influence energy sharing. Based on current evidence, we hypothesized that monetary incentives would enhance householders' willingness to provide energy when asked to do so. We had no clear expectations regarding donations.

1.2 Energy resource scarcity

Energy research has investigated what adaptations householders make to cope with power outages [e.g.22], but not their willingness to share their own limited supply during such events. Given current evidence, energy resource scarcity is likely to produce some counter-intuitive results. For example, if people only had a fixed, very limited energy supply, would they willingly share it with a public service to keep it functioning? Research has shown that when material resources are scarce, this may induce a competitive mindset [23] which can influence decision-making because of its impact on cognitive capacity [24-26]. In particular, Shah and colleagues [24, 25], found that a scarce resource draws in more attentional focus resulting in greater engagement. This may, in turn, lead to decision-making based on a trade-off approach underpinned by more stable internally generated standards rather than the more typical external contextual factors which may be unpredictable [25]. However, there are instances where people have reacted to resource scarcity by hoarding consequent to external cues such as information from social media, business or government [27]. Similarly, bank runs and panic-buying have occurred following a perceived rather than actual threat of loss/scarcity. Sheth [28] argued that such actions occur in a crisis to manage feelings of uncertainty. Indeed, Omar and colleagues [29] found in their COVID-19-related survey (n=157) regarding food panic-buying that participants' perceptions of uncertainty about and severity of the pandemic as well as perceived food scarcity were positively associated with levels of anxiety and consequent panic-buying. Their results concur with existing literature linking perceptions of scarcity and anxiety to panic-buying and highlights the pivotal role of anxiety in an inter-group context in mediating this behaviour (ibid). On the other hand, crisis events have also resulted in changes in purchase behaviour that are pro-social. For example, during the Fukushima nuclear disaster in Japan, evidence showed that consumers intended to increase their purchases following product contamination, to help the affected community [30]. Frank and Schvaneveldt [30] argued that consumers' empathetic response may have been driven by the saliency of social identity with the disaster victims. Aligned with this, Bucher et al. [5] showed that at least some motives for sharing are underpinned by the desire to help and care for others. Scarcity is strongly associated with perceived value and, in line with developmental findings, Louie et al. [31] demonstrated that when participants experience scarcity, they may behave more pro-socially. The authors showed that, within their scarce condition, when participants could choose the scarce item (favourable experience), they were more likely to donate while those in their 'not scarce' condition donated the least. We therefore hypothesized that energy scarcity (amount of energy currently available) would influence the extent to which householders would be willing to share what they had with others in need.

1.3 Settlement type

'Settlement type' or where householders live, may be classified as either 'rural' or 'urban'. The UK government uses the "Rural Urban Classification" (RUC) for England and Wales and defines urban areas as "…the connected built up areas identified by Ordnance Survey mapping that have resident populations above 10,000 people (2011 Census)" [32]. Rural areas are defined as "…those areas that are not urban i.e. consisting of settlements below 10,000 people or are open countryside" [32]. In a government report regarding England, those living in rural communities reported feeling more favourably about their local neighbourhood relative to urban dwellers and they volunteered more [33]. Charitable donations were comparable (ibid). We found no other published research that directly compares urban to rural settlements' sharing of essential resources within the UK or England. According to Bradley [34], economic, social and physical environmental factors are more likely to determine differences in behaviour and development than whether a living environment is urban or rural. Given how little is known regarding urban vs. rural households' sharing behaviour, the present study sought to address this knowledge gap, particularly in the context of energy sharing. We hypothesized that settlement type (urban vs. rural) may affect householders' willingness to provide energy.

1.4 Summary of Aims

This project aimed to experimentally test householders' willingness to share their own limited electricity with a local hospital during a hypothetical energy-shortage crisis. We used vignettes that manipulated monetary incentives, energy scarcity conditions and settlement type. The study makes a novel contribution because previous research has not jointly examined these factors within the context of restricted availability affecting both households and critical community services. Our findings will contribute to the literature by demonstrating how resource scarcity and monetary incentives interact with factors such as settlement type to influence energy-sharing decisions under crisis conditions such as may occur in a future green energy grid.

2 Method

Participants were invited to take part in a study about when and why householders might buy and sell energy in the future. The study began by providing an explanation of the way in which a switch to green energy sources could lead to power shortages (see Supplement 2). Using a vignette-based experimental study, we examined householders' willingness to share their limited electricity supply with a local hospital during a hypothetical energy-shortage crisis. Vignettes are brief, hypothetical scenarios that depict particular events or situations and are used to elicit behavioural responses in empirical research. In this study, the vignettes were designed to engage participants by creating a 'story' that both urban and rural participants could easily imagine. They were told that there was a UK-wide power outage during which they would have up to 7 days' normal household energy usage drawn from their EV battery. Variations in monetary incentive and level of energy availability were randomly assigned, using a between-subjects design.

This experimental vignette-based study was conducted in three iterations: Study 1, Study 2 and Study 3, described and reported in the sections that follow. Study 1 was preregistered (https://aspredicted.org/YPF_HSJ), whereas Studies 2 and 3 were conducted *post hoc* to further investigate the findings from Study 1.

2.1 Power Calculation

GPower v.3.1.9.7 [35] and Cohen's [36] effect sizes: 0.2, 0.5 and 0.8 for small, medium and large effect sizes were used for statistical power calculations. For Study 1, we estimated that, for an effect size of 0.2 at a power of .95 and alpha of .05 we would need a total N = 440 (55 per condition) for a 4 x 2 between-subjects ANOVA. For Study 2 we collected about double the required N to measure the additional condition. For Study 3, the same criteria would require N = 429 for a 3 x 2 between-subjects ANOVA. We increased it to N=480 (80 per condition) to account for technical issues/exclusions. Supplement 1 provides GPower calculations.

2.2 Participants

In total, 1,135 participants [608 (54%) females] were invited to participate. Study 1 had 505 participants, Study 2 had 126 participants and Study 3 had 497 participants. All samples were independent. Eligible participants resided in England, aged 18 to 65 and either wholly or partially responsible for paying the household's energy bills. In addition, they had to have been driving a car within the last 2 years. The latter criterion was to ensure a relatively homogeneous level of familiarity with the EV-based narrative of the scenario.

Participants were recruited anonymously using two panels: MSI-ACI Europe BV, a data management company, for Study 1 and Prolific, an online participant recruitment platform, for Studies 2 and 3. All studies were administered exclusively online using Qualtrics. Recruitment and testing took place from January 2024 to July 2024.

Online informed consent was given after reading a full description of the study and before participation began. This study was approved by the Science and Health Faculty Ethics Subcommittee 1 of the University of Essex [ETH2324-0240, 20/12/2023]. All procedures complied with relevant laws and institutional guidelines.

2.3 Design and procedure

2.3.1 Randomisation checks

Prior to the main analyses, we determined equivalence of random assignment to condition for age, gender, education and income using Analysis of Variance (ANOVA) or chi square, as appropriate. The randomisation procedure was executed automatically using the Qualtrics built-in randomiser software. Random assignment in each scenario was independent of the other. The randomiser assigned participants to a condition in each experiment. Participants were sampled (0.5/0.5) from two settlement types in England: a) urban and b) rural post codes. The research team were blind to group-allocation until after data collection was complete.

2.3.2 Statistical Analysis

Both frequentist and Bayesian statistical methods were applied. Analysis of Variance was used to measure differences between group means in the main analysis. Where distributions were skewed, Kruskal-Wallis test outcomes were also reported where possible. Alpha levels were set to < .05 and Bonferroni-corrected where necessary. Corresponding Bayesian analyses were performed alongside frequentist analyses where possible.

Bayes Factors are reported alongside p-values. A Bayes factor (BF) of >3 provides evidence roughly equivalent to a p-value of 0.05 [37] supporting the alternative hypothesis and a BF of <0.33 provides evidence for the null while anecdotal evidence (i.e. inconclusive) is indicated by $0.33 \leq BF \leq 3.0$. Thus, BFs avoid the “reject or fail-to-reject” outcomes associated with frequentist methods by providing a range of possible values [38]. Where BF and p-values diverged, conclusions were based on the BFs which are more nuanced, providing evidence for the alternative hypothesis relative to the null. Bayes factors were computed with JASP version 0.18 using the default prior parameters [39].

2.3.3 Study 1 Design and Analysis

Using a between-subjects design we evaluated, in a single session, the impact of different a) price and b) energy availability conditions along with c) settlement type and its interaction with a) and b), respectively, regarding the amount of energy shared. Amount of energy shared was measured in quarters of one day and then converted into total number of hours. Total number of hours served as the dependent measure for all analyses in this report. Figure 1 presents Study 1's design alongside follow-up studies.

Study 1 comprised two vignettes, presented in fixed order:

Scenario 1a (price by settlement type) measured the impact of monetary incentive, operationalised as 'price' and settlement type. Participants were randomly assigned to one of four price conditions within settlement type as shown in Fig. 1.

Scenario 1b (available energy by settlement type) measured the impact of how scarce participants' energy was and settlement type on amount of energy shared. Participants were randomly assigned to one of three energy scarcity conditions, operationalised as 'energy availability', detailed in Fig. 1.

	Scenario 1a		Scenario 1b	
Study 1	**Settlement Type**	**Monetary Incentive ('price')**	**Settlement Type**	**Energy scarcity ('energy availability')**
Constant		7 days' energy available:		*Sell* at the same price as paid:
	Urban	• Give for free (0.0) • Sell at half paid (0.5) • Sell at same as paid (1.0) • Sell at twice as paid (2.0)	Urban	• 1 day's energy available • 3 days' energy available • 5 days' energy available
	Rural		Rural	
Study 2		**Monetary Incentive ('price')**		
Constant		7 days' energy available:		
		• Sell at 1/10th paid (0.1)		
	Scenario 3a		**Scenario 3b**	
Study 3	**Monetary Incentive Type**	**Monetary Incentive ('price')**		**Energy scarcity ('energy availability')**
Constant		7 days' energy available:		*Give* at the same price as paid:
	Give	• (Give) for free (0.0) • (Give) at 1/10th paid (0.1) • (Give) at twice as paid (2.0)		• 1 day's energy available • 3 days' energy available • 5 days' energy available
	Sell	• (Sell) for free (0.0) • (Sell) at 1/10th paid (0.1) • (Sell) at twice as paid (2.0)		

Fig. 1. Designs for Studies 1, 2 and 3
Study 1 comprised 2 vignettes: Scenario 1a and Scenario 1b.
Study 2 comprised 1 vignette: Scenario 1a (with new level: sell at 1/0th paid).
Study 3 comprised 2 vignettes: Scenario 3a and Scenario 3b.

Scenario 1a Main Analysis: A 4 (price: free, half paid, same as paid, twice paid) x 2 (settlement type: urban, rural) factorial ANOVA with the dependent variable being the number of hours shared. Energy availability was held constant (EV battery sufficient for up to 7 days of normal usage).

Scenario 1b Main Analysis: A 3 (available energy: 1 day, 3 days, 5 days) x 2 (settlement type: urban, rural) factorial ANCOVA controlling for car type ('petrol/diesel', 'EV', 'hybrid') on the number of hours shared. Price was held constant at "sell at same as paid".

Post hoc tests were conducted to follow up all significant results.

2.3.4 Study 2 Design and Analysis

We realised, *post hoc*, that differences in the wording (framing) of the price conditions in Scenario 1a (Fig. 1) may have elicited different mindsets (will you give vs. will you sell) and, consequently, bias participants' responses. To explore this, we assessed whether a change of framing from 'giving for free' to 'sell at a minimal price' would make a difference to the amount of energy shared. Thus, Study 2 was conducted as an *addendum* to Study 1. As shown in Fig. 1, participants received only the Scenario 1a vignette with only one new condition. We then analysed this additional data with Study 1 data.

Study 2 Main Analysis: A one-way ANOVA for price (free, a tenth paid, half paid, same as paid, twice paid) on hours shared.

Planned follow-up tests: First, an *a priori* linear contrast tested the hypothesised linear increase across the four 'sell' levels ($1/10^{th}$ paid, half paid, same as paid, twice paid) with weights -3, -1, 1, 3, respectively. Secondly, an independent samples t-test compared 'free' vs. '$1/10^{th}$ paid' to evaluate whether 'free' framing offset perceived loss relative to negligible compensation under 'sell' framing.

2.3.5 Study 3 Design and Analysis

Study 3 (price by incentive type), also presented in Fig. 1, was conducted *post hoc* and comprised a partial replication of Study 1. Again, we wanted to provide further clarity to Study 1 statistical outcomes by assessing the impact of subtle wording changes in the request for energy. Study 3 was similar to Study 1 but with these two changes: a) 'settlement type' was replaced by a new variable: 'monetary incentive type' (give vs. sell). This is because 'giving' is often associated with charitable actions, e.g. charitable giving, while 'selling' typically applies in the context of monetary transactions; and b) price conditions were added/changed, shown in Fig. 1.

Study 3a Main Analysis: A 3 (price: free, 1/10th paid, twice paid) x 2 (incentive type: give, sell) factorial ANOVA on the number of hours shared.

Study 3b Main Analysis: A one-way ANOVA measuring the impact of 'giving' available energy (1 day, 3 days, 5 days) on the number of hours shared.

Post hoc tests were conducted to follow up all significant results.

2.3.6 Pooled confirmatory analyses (cross study):

Capitalising on the statistical power of a larger sample, we combined our 3 studies' data and re-tested the impact of price and incentive type on number of hours shared using the same 3 x 2 ANOVA as before.

Price by Incentive Type Pooled Analysis: A 3 (price: free, 1/10th paid, twice paid) x 2 (incentive type: give, sell) factorial ANOVA on the number of hours shared. Study 3 data was combined with Study 1 (free, twice paid) and Study 2 ($1/10^{th}$ paid) data as applicable.

Available Energy by Incentive Type Pooled Analysis: A 3 (available energy: 1 day, 3 days, 5 days) x 2 (incentive type: give, sell) factorial ANOVA on the number of hours shared. Scenario 1b (sell) and Scenario 3b (give) were pooled to evaluate whether sharing as a function of energy-availability was sensitive to framing.

Post hoc tests were conducted to follow up all significant results.

Fig. 2 presents the procedure for Study 1, which comprised two experimental tasks preceded by a sociodemographic questionnaire, followed by self-report questionnaires. Attentional checks, a comprehension task and distractor task were also given. Studies 2 and 3 were very similar regarding procedure and median completion time.

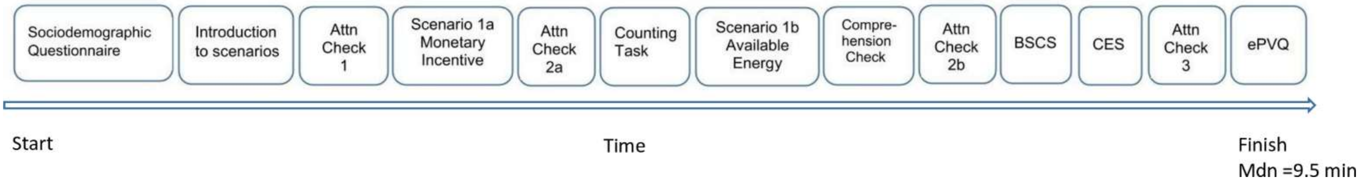

Fig. 2. Study 1 procedure
Participants completed all measures within an online survey, starting with a sociodemographic questionnaire. They then viewed an infographic about energy grids, power outages and battery storage followed by Attention Check 1 and were randomly assigned to a version of Scenario 1a. Attention check 2 (part 1) was administered next, followed by a distractor (counting) task. Participants were then randomly assigned to a version of Scenario 1b, then a comprehension check and Attention Check 2 (part 2). They subsequently completed the Brief Sense of Community Scale (BSCS) and Civic Engagement Scale (CES) followed by Attention Check 3, concluding with the Environmental Portrait Value Questionnaire (ePVQ).

Study 2 included only one experimental task while Study 3 included two experimental tasks; otherwise their procedures were similar to that of Study 1. Their median completion times were also very similar.

2.4 Materials

2.4.1 Socio-demographic Questionnaire

Supplement 2 provides a full copy of each survey. Briefly, participants gave demographic information, annual income and how sufficient they thought their monthly resources were to pay for fixed expenses on a 5-point scale (‘very insufficient’ to ‘very sufficient’). Next were questions regarding type of dwelling (e.g. ‘house or bungalow’, ‘flat, maisonette or apartment’), whether they rented/owned their own home and whether they lived alone/with others (e.g. ‘child(ren) under 12 yrs’). They also gave the first part of their post code and self-reported their settlement type (‘major city’, ‘city’, ‘town’, ‘village’ or ‘hamlet’). Finally we explored whether urban and rural areas engendered differences regarding technological connectedness and pro-social propensity, participants reported how sufficiently connected they felt regarding their mobile phone network and internet connection (‘extremely dissatisfied’ to ‘extremely satisfied’), whether they identified with their local region and how environmentally conscious they were (‘strongly disagree’ to ‘strongly agree’).

2.4.2 Experimental tasks

Supplement 2 contains the scenario scripts within each study survey. In all scenarios, participants were asked to imagine that they owned an electric vehicle (EV); there had been a major incident and everyone would be at risk of being without power for up to 7 days. In addition, the hospital’s back-up system had failed leaving them without the necessary power to perform essential functions including lighting up operating theatres and keeping ventilators and other critical care equipment working. Participants were also told that they would be able to draw energy from their EV to power their home.

Below we provide details for Study 1 (note: Study 2 and 3 were very similar and are detailed in Fig. 1 and Supplement 2):

Scenario 1a: we measured price, keeping energy availability constant; participants were informed that they would have up to 7 days’ normal energy usage from their EV battery. Participants were then asked if they would help keep the hospital running by, for example, giving power from their EV battery to the hospital for free or, for example, selling power from their EV battery to the hospital for twice what they paid.

Scenario 1b: we measured energy availability, keeping price constant; participants were informed that they would sell [Scenario 3b: ‘give’] energy at the price they paid. Here, participants were asked if they would help keep the hospital running by selling [Scenario 3b: giving] up to one day's power from their EV to the hospital given that they had, for example, one day's normal energy available or for example, five days' normal energy available. Recall that participants knew that they may be without power for up to 7 days.

2.4.3 Settlement type sampling strategy

We used the Office of National Statistics' Rural Urban Classification (RUC) [40]. Urban and rural settlment types were classified on this basis using post codes. Supplement 3 provides the full details of how post codes were derived. Our aim was to compare typically representative urban and rural groups. Urban areas were chosen to represent the East, West, North and South of England. For this purpose an urban sample was drawn from Birmingham, Liverpool, Bristol, Manchester, Sheffield, Leeds, Hull (Kingston-upon-Hull) and Southampton. A rural sample was drawn from all over England to maximise finding sufficient, suitable participants within the time-limit of our project. London was excluded entirely because it does not represent a typical urban (or rural) location. It has a much higher population density, highly diverse and structurally different housing stock, transport patterns and energy-use characteristics compared to other English urban settlements [41-43]. For example London is home to ~9 million people relative to the next largest UK city, Birmingham (~1.183 million people). Londoners rely considerably more on public transport relative to cars (~12% vs.10%) than other major cities such as Birmingham (~5% vs. 18%) and Leeds (4% vs. 19%). Moreover, ~40% of London residents live in apartment blocks relative to Birmingham (~21%) and Leeds (~17%). Consequently, Londoners' willingness to share scarce energy with their local hospital in an emergency may be strongly biased by public transport links, type of accommodation and the like relative to other urban settlements in England.

2.4.4 Other measures

We measured sense of community, civic engagement and personal values using the Brief Sense of Community Scale (BSCS) [44], Civic Engagement Scale (CES) [45] and the Environmental Portrait Value Questionnaire (ePVQ) [46], respectively. For brevity, these findings will be published separately. Supplement 2 provides all questions.

2.4.5 Data quality and attention tasks

Directly after the experiment, we administered a comprehension check to ensure that participants correctly identified the study's objective; those who failed were excluded. Three attention checks were embedded throughout the survey. To minimise carry-over effects between vignettes, participants also completed a brief distractor task. Full details are provided in Supplement 4.

3 Results

3.1 Study 1

Our final sample comprised 447 participants (269 females) with a median age of 38 (IQR: 29-51); 58 participants failed the comprehension test and were excluded. Random allocation was successful for all variables (p's ≥ .075; BF ≤ 0.01), shown in Table 1a for price and Table 1b for available energy. Supplement 4 provides additional details. Supplement 5 presents descriptive statistics results for the remaining sociodemographic variables. No statistically significant associations were revealed for any measures for price (p's ≥ .124; BF's ≤ 0.14) or available energy (p's ≥ .326; BF's ≤ 0.09).

Table 1a. Study 1 Sociodemographic variables by price.

		give for free (donate) n=112	half of what was paid n=115	same as what was paid n=111	twice what was paid n=109	p	BF[d]
Age[a]	Mean (SD)	39.3 (13.5)	39.3 (13.6)	40.2 (13.2)	40.4 (12.7)	0.880	0.01
Gender[b]	female:male	69:41	74:41	64:45	62:43	0.783	0.01
Education[b]	university/other tertiary education	78	82	80	78	0.256	< 0.01
	secondary school (A-level or equivalent)	8	14	9	10		
	secondary school (GCSE or equivalent)	22	18	22	21		
	Other	4	1	0	0		
Annual Income[c]	less than £20,000 per year	18	14	22	16	0.075	< 0.01
	£20,001 to £40,000	40	47	43	40		
	£40,001 to £60,000	29	22	21	23		
	£60,001 to £80,000	14	22	8	12		
	80,001 to £120,000	9	4	11	16		
	more than £120,000	2	6	6	2		

*p < .05; **p < 0.01

[a] One-way ANOVA.

[b] Pearson Chi Square for independence. Non-binary (n=1) and 'other' (n=7) gender categories were excluded from analysis.

[c] Chi Square for independence performed but we report Likelihood Ratio test results because of some small cell sizes.

[d] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.

*Note***:** sample sizes varied slightly for different comparisons, therefore numerical values rather than percentages have been given in all cases except for age.

Table 1b. Study 1 Sociodemographic variables by amount of available energy.

		1 day's energy avail n=147	3 days' energy avail n=148	5 days' energy avail n=152	p	BF[d]
Age[a]	Mean (SD)	40.3 (13.1)	38.9 (13.1)	40.2 (13.5)	0.618	0.04
Gender[b]	female:male	84:60	92:55	93:55	0.676	0.03
Education[b]	university/other tertiary education	107	105	106	0.558	<0.01
	secondary school (A-level or equivalent)	9	17	15		
	secondary school (GCSE or equivalent)	30	25	28		
	Other	1	1	3		
Annual Income[b]	less than £20,000 per year	21	24	25	0.012*	0.01
	£20,001 to £40,000	60	67	43		
	£40,001 to £60,000	34	29	32		
	£60,001 to £80,000	13	11	32		
	80,001 to £120,000	15	13	12		
	more than £120,000	4	4	8		

*p < .05; **p < 0.01
[a] One-way ANOVA.
[b] Pearson Chi Square for independence. Non-binary (n=1) and 'other' (n=7) gender categories were excluded from analysis.
[c] Chi Square for independence performed but we report Likelihood Ratio test results because of some small cell sizes.
[d] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.
Note: sample sizes varied slightly for different comparisons, therefore numerical values have been given in all cases except for age.

We tested vehicle type between groups to rule out whether being an EV owner might influence the results. We created 4 broad categories, 'petrol/diesel' (no EV or hybrid selected), 'EV' (selected irrespective of others) and 'hybrid' (selected hybrid but not EV) and 'other' (dual-fuel only). As 'other' comprised only 3/477 observations, analyses used the first three categories (see Supplement 5). A Pearson Chi Square test found that groups were comparable for price (p = .392; BF < 0.01) but not energy availability, which showed a positive association ($\chi^2(4)$ 18.482, p = .001; BF = 2.94). Adjusted residuals indicated this was mainly driven by the 3- and 5-day levels for 'petrol/diesel' owners, the 3-day level for EV owners and 5-day level for hybrid owners.

Given the differences in vehicle owners for the available energy variable, we included this as a covariate in its main analysis.

Finally, we evaluated the shape of both price and available energy distributions using Kolmogorov-Smirnov tests and visual inspection. Both were skewed (p's < .001). The main analyses therefore included Kruskal-Wallis tests to evaluate main effects alongside parametric and Bayesian ANOVAs which we report as planned given that the sample sizes were large and therefore robust to violations of the normal distribution assumption.

3.1.1 Main Analysis

The ANOVA revealed a main effect for price only (F(3,439) 3.598, p = .014, η_P^2 = 0.024), presented in Table 2a. Neither the main effect for settlement type nor the price by settlement type interaction were statistically significant (p's ≥ .545). These results are provided in Supplement 5-Table 2. The corresponding Bayesian ANOVA model comparison results indicated that, relative to the null (BF_{10} = 1.00), the model including only price was 1.16 more likely (BF_{10} = 1.16) while respective price and settlement type main effects models and the model comprising both main effects and their interaction were less likely than the null (BF_{10}'s ≤ 0.14). As an *addendum*, possibly redundant, the BF of 0.06 comparing the interaction model and the two main effects models indicates that the interactive effect did not receive support from the data (Supplement 5-Table 2). The Kruskal-Wallis tests for the main effects were congruent with a significant result for price (χ^2(3, n=447) 8.638, p = .035) but not settlement type (p = .80).

Table 2a. Study 1 Means, SE, ANOVA and Bayes Factors for hours of energy shared by price.

			Main Effects		
Overall Price	**Mean (SE)**	**95% CI**	**F**	**p**	**BF[a]**
give for free (donate) (n=112)	68.27 (5.03)	58.37, 78.16	3.598	0.014*	1.16
half of what was paid (n=115)	49.15 (4.91)	39.51, 58.79			
same as what was paid (n=111)	68.58 (4.95)	58.86, 78.31			
twice what was paid (n=109)	66.38 (4.99)	56.57, 76.2			

* $p < .05$; ** $p < 0.01$; *** $p < .001$

[a] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.

Referring to Fig. 3a, *post hoc* Tukey price tests revealed statistically significant differences in sharing behaviour between free (M 68.27, SE 4.91) and half paid (M 49.15, SE 4.91) sub-groups (p = 0.034) and between half paid (M 49.15, SE 4.91) and same as paid (M 68.58, SE 4.95) sub-groups (p = 0.028). No other comparisons were statistically significant (p's ≥ 0.068). Bayesian *post hoc* comparisons of price provided moderate evidence for a difference between free vs. half paid (BF = 9.20), half paid vs. same as paid (BF = 6.32) and half paid and twice paid (M 66.38, SE 4.99) (BF = 3.13) sub-groups. The remaining 3 comparisons revealed no differences between free vs. same as paid, free vs. twice paid and same as paid vs. twice paid groups, evidenced by support for the null (BFs ≤ 0.16). The Bayesian outcomes broadly agree with the Tukey results. Taken together, these results suggested that, independent of settlement type, participants who were asked to donate, shared relatively more energy than those asked to sell at half-price. Likewise, participants asked to sell at zero loss (same as paid) or at profit (twice paid) also shared more than those selling at half-price. Importantly, those who donated shared a very similar amount of energy with the hospital relative to the same as paid and twice paid sub-groups.

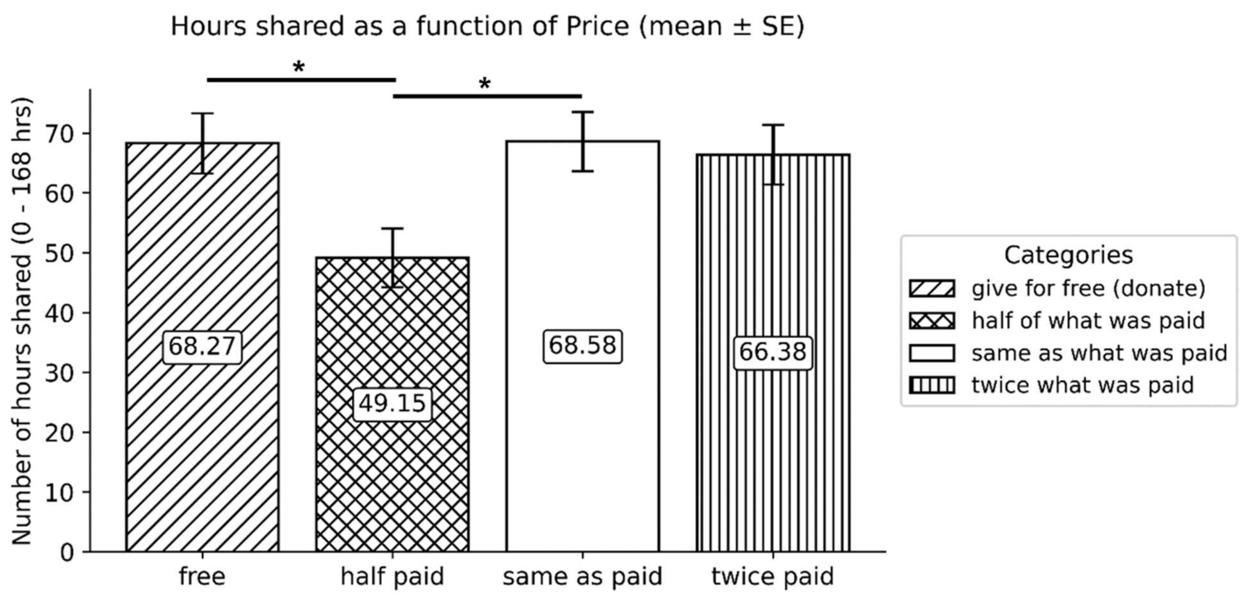

Fig. 3a. Study 1: Price main effect (mean ± SE, 95% CI)
Mean number of hours shared for each price condition.
*p < 0.05

The ANCOVA revealed a statistically significant main effect for available energy (F(2,437) 18.906, $p < .001$, $\eta^2_P = 0.082$), shown in Table 2b. Neither the main effect for settlement type nor the 2-way interaction were statistically significant (p's ≥ .313) as shown in Supplement 5-Table 2. Moreover, the impact of vehicle type was not statistically significant (F(1,437) <2, $p = .182$). A Bayesian ANOVA was conducted as JASP does not accommodate categorical variables as covariates, thus car type was not controlled for. The model comparison results showed that, relative to the null ($BF_{10} = 1.00$), the model including only the available energy main effect was exceedingly more likely ($BF_{10} > 100$). The only model less likely than the null was the model including only settlement type ($BF_{10} = 0.11$). As an *addendum*, the BF of 0.117 comparing the interaction model and the two main effects model indicates that the interactive effect did not receive support from the data (Supplement 5-Table 2). The Kruskal-Wallis tests revealed a statistically significant result for available energy $\chi^2(2, n=447)$ 39.032, $p < .001$) but not for settlement type ($p = .767$).

Table 2b. Study 1 Means, SE, ANCOVA and Bayes Factors for hours of energy shared by available energy.

	Main Effects				
Overall Available Energy	**Mean (SE)**	**95% CI**	**F**	**p**	**BF[a]**
1 day's energy avail (n=147)	11.13 (0.71)	9.73, 12.54	18.906	< .001***	> 100
3 days' energy avail (n=148)	14.88 (0.72)	13.46, 16.29			
5 days' energy avail (n=152)	17.25 (0.70)	15.87, 18.62			

* p < .05; ** p < 0.01; *** p < .001

[a] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.

Post hoc Tukey follow-ups for available energy, presented in Fig. 3b, revealed that the 5-day sub-group (M 17.25, SE 0.70) shared statistically significantly more energy than the 3-day (M 14.88, SE 0.72) or 1-day (M 11.13, SE 0.71) sub-groups (p's < .001) while the 3-day sub-group shared more than the 1-day sub-group ($p = .034$). The Bayesian follow-ups were similar with extremely strong evidence for a difference between 1-day vs. 3-day sub-groups and 1-day vs. 5-day sub-groups (BFs > 100) but evidence was inconclusive for 3 vs. 5 day sub-groups (BF = 1.53). We noticed that 1-day participants shared proportionately more of their available energy, on average (11.13 of 24 hrs, i.e. 46.8%), than their 3 and 5 day counterparts (14.88 of 72 hrs; 20.7%; 17.25 of 120 hrs; 14.4%, respectively). One possible reason for this is that the upper limit of 1 day placed a constraint upon the 3-day and 5-day sub-groups' generosity. Alternatively, these two groups were less generous than the 1-day group. To investigate this we compared the 1, 3 and 5 day sub-groups by proportions of participants who gave 1 day's energy vs. those who gave less than 1 day's energy. If the former, we should find that the proportion of 1-day sharers increased as a function of days of available energy. Indeed, this is what the statistically significant Pearson chi square ($\chi^2(2, n=447)$ 40.977, $p < .001$) and equivalent Bayesian analysis (BF > 100) indicated. The percentage of participants within each group who gave 1 day increased as the energy available level increased: 19% (1 day) < 42.6% (3 days) < 54.6% (5 days).

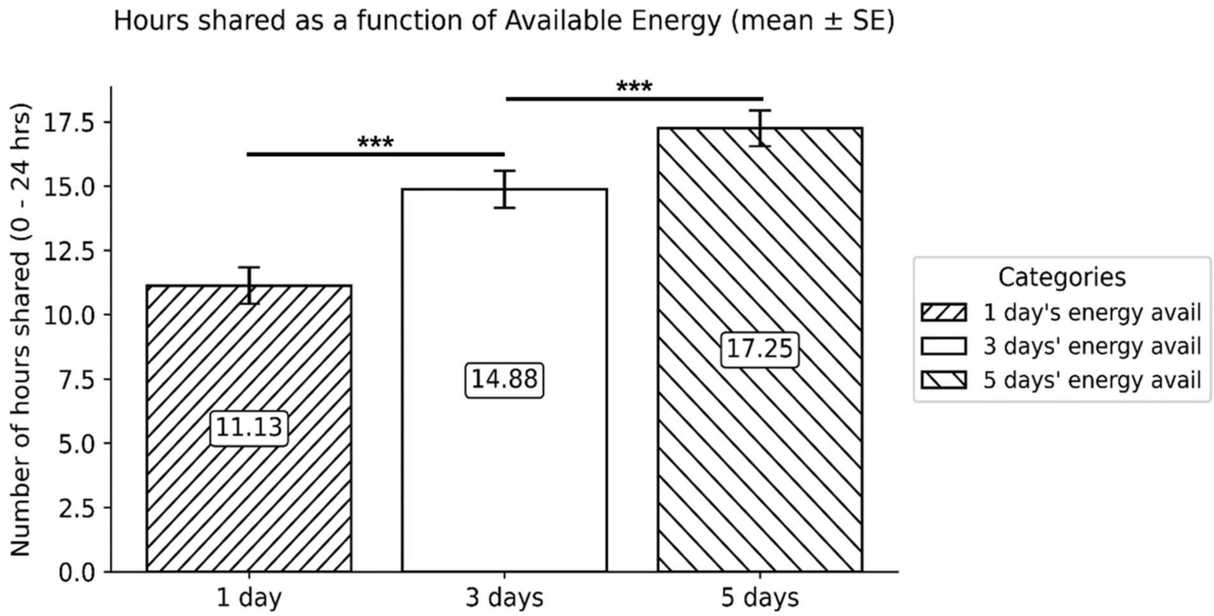

Fig. 3b. Study 1: Available Energy main effect (mean ± SE, 95% CI)
Mean number of hours shared for each availability condition.
*p < 0.05; **p < 0.01; ***p < 0.001

Our findings therefore indicated that, whether energy supply was quite scarce or very scarce, participants gave generously. When comparing the sub-groups, those who had more days' energy available (less scarce) gave significantly more, though proportionately less. In both experiments, energy sharing patterns were similar among urban and rural participants.

3.2 Study 2

Of 126 participants, 120 (58 females) individuals, median age: 42 (IQR: 34-53.8), passed the comprehension check.

In Study 1's Scenario 1a, some participants were asked to 'give' (for free) energy while others were asked to 'sell' (at half, same or twice what they paid) potentially creating different mindsets between the 'free' (charitable) and 'sell' (financially incentivised) groups. This seems likely given that the give sub-group responded similarly to the same as paid and twice paid sub-groups all of which were significantly more generous in sharing their energy with the hospital than the half-paid participants. Consequently, Study 2 tested a further condition, 'selling energy at a 10^{th} of what was paid', to explore the hypothesis that participants who were financially motivated would not expect financial loss (e.g. sell at half of what you paid) but if a financial loss were incurred (e.g. give for free), it was acceptable if perceived as a donation. Comparing a 'sell' condition of a tenth paid offers a meaningful comparison to the 'give (for free)' condition, but importantly the framing ('sell') would be the same across all levels of price thereby allowing us to clarify our results for Study 1, Scenario 1a.

Based on the above, we expected a significant linear trend in the amount of energy shared with the hospital when comparing the 4 'sell' price conditions (sell at a 10^{th} paid, half paid, same as paid, twice paid). Conversely, when comparing the hours shared we would expect to see the $1/10^{th}$ paid sub-group share significantly less energy than the 'give for free' (free) sub-group even though they are conceptually similar (free vs. being paid a negligible amount for the energy). Given that no difference in sharing behaviour were observed for rural and urban participants in Study 1, this factor was dropped from further analysis.

3.2.1 Main Analysis

The one-way ANOVA for price revealed a statistically significant result ($F(4,562)$ 5.109, $p = .001$, $\eta_P^2 = 0.035$). In addition, the contrast test was statistically significant ($F(1,451)$, 12.892, $p < .001$; $CI_{95\%}$: 33.43, 114.29), while the t-test revealed that the free sub-group (M 69.48, SE 5.28) gave significantly more than the 1/10th paid sub-group (M 47.8, SE 4.1), ($t(230)$ 3.267, $p = .001$; $CI_{95\%}$: 8.61, 34.76). The Bayesian one-way ANOVA revealed strong evidence (BF = 22.35) in favour of a difference between the groups. The Bayesian t-test evaluating free vs. 1/10th paid sub-groups agreed with the frequentist result, providing strong evidence (BF = 20.45) for a difference in hours of energy shared between these groups. Given the skewed distribution for hours shared, a Mann-Whitney U was also conducted with comparable results ($U = 5226$, $p = .003$).

Together these results supported our hypotheses that a charitable (give for free) mindset negates the negative effect of a financial loss on sharing behaviour whereas a financially incentivised (sell at 1/10th paid) mindset does not. Consequently framing ('give' vs. 'sell') may be important when asking people to share energy. To confirm our results, we conducted a further follow-up study.

3.3 Study 3

Study 2's results showed that, as expected, there was a significant linear trend in the amount of energy shared as a function of the monetary value paid. Furthermore, the difference between the free and the 1/10th paid condition appeared to be significant. Our aim in Study 3 was to confirm our hypothesis that framing matters in nudging individuals towards a switch to prosumerism. In this study we manipulated monetary incentive (‘price’) as follows: free, 1/10th paid and twice paid, using either a ‘giving’ or ‘selling’ framework for Scenario 3a. In Scenario 3b we administered the experiment exactly as in Study 1 but changed ‘sell’ to ‘give’ (see Fig. 1). We expected that if giving induces a charitable mindset the amount of energy shared with the hospital would not measurably differ across price or available energy conditions. However, when selling, energy shared was expected to vary.

3.4 Results

Our final sample was 484 participants (242 females), median age = 39 (IQR: 32-50); 13 participants had been excluded because they failed the comprehension check. Random allocation was successful for all variables for price and available energy indicated in Table 3a and Table 3b, respectively. Supplement 4 provides additional details. Supplement 5 provides sociodemographic descriptive statistics. None were statistically significant (p’s ≥ .140; BFs ≤ .30), as shown.

Table 3a. Study 3 Sociodemographic variables by price split by give vs. sell framework.

		give framework			sell framework				
		give for free (donate) n=81	**1/10th paid n=80**	**twice what was paid n=80**	**sell for free (donate) n=82**	**1/10th paid n=80**	**twice what was paid n=81**	**p**	**BF[d]**
Age[a]	Mean (SD)	41.47 (12.01)	40.54 (10.79)	42.6 (11.32)	39.48 (11.56)	40.78 (10.85)	41.54 (11.42)	0.616	< 0.01
Gender[b]	female:male	41:40	43:37	33:47	43:39	37:43	45:36	0.472	< 0.01
Education[b]	university/other tertiary education	67	70	66	71	66	71	0.724	< 0.01
	secondary school (A-level or equivalent)	7	7	6	5	5	6		
	secondary school (GCSE or equivalent)	7	3	8	6	9	3		
	Other[d]	0	0	0	0	0	1		
Annual Income[c]	less than £20,000 per year	5	3	3	2	11	8	0.590	< 0.01
	£20,001 to £40,000	26	28	20	27	27	28		
	£40,001 to £60,000	26	21	18	28	19	20		
	£60,001 to £80,000	15	12	22	17	14	8		
	80,001 to £120,000	6	15	12	6	6	14		
	more than £120,000	3	1	5	2	3	3		

*p < .05; **p < 0.01

[a] One-way ANOVA.

[b] Pearson Chi Square for independence.

[c] Chi Square for independence performed but we report Likelihood Ratio test results because of some small cell sizes.

[d] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.

Note: sample sizes varied slightly for different comparisons, therefore numerical values rather than percentages have been given in all cases except for age.

Table 3b. Study 3 Sociodemographic variables by available energy condition using the give framework.

		give framework				
		1 day's energy avail n=160	**3 days' energy avail n=164**	**5 days' energy avail n=160**	**p**	**BF**[d]
Age[a]	Mean (SD)	40.92 (11.76)	40.86 (11.45)	41.41 (10.79)	0.891	0.03
Gender[b]	female:male	77:83	88:76	77:83	0.515	0.03
Education[b]	university/other tertiary education	138	138	135	0.851	< 0.01
	secondary school (A-level or equivalent)	11	13	12		
	secondary school (GCSE or equivalent)	10	13	13		
	Other[d]	1	0	0		
Annual Income[c]	less than £20,000 per year	13	13	6	0.153	< 0.01
	£20,001 to £40,000	56	50	50		
	£40,001 to £60,000	41	40	51		
	£60,001 to £80,000	26	33	29		
	80,001 to £120,000	20	17	22		
	more than £120,000	4	11	2		

*p < .05; **p < 0.01

[a] One-way ANOVA.

[b] Pearson Chi Square for independence.

[c] Chi Square for independence performed but we report Likelihood Ratio test results because of some small cell sizes.

[d] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.

Note: sample sizes varied slightly for different comparisons, therefore numerical values have been given in all cases except for age.

Kolmogorov-Smirnov tests and visual inspection, as in Study 1 and 2, revealed that both price and available energy distributions were skewed (p's < .001). Given our large sample, we proceeded with ANOVAs and Bayes Factors, supplementing with Kruskal-Wallis tests where possible as before.

3.4.1 Main Analysis

Study 3 descriptive statistics, ANOVA and BF results for price are presented in Table 4. The table shows a statistically significant main effect for price only ($F(2,478)$ 6.187, $p = .002$, $\eta_p^2 = 0.025$). For Study 3a, neither the main effect for incentive type (giving vs. selling) nor its interaction with price were statistically significant (p's ≥ .725). Supplement 5-Table 4 includes price by incentive type means, standard errors and 95% confidence intervals. Similarly, the Bayesian ANOVA model comparison results indicated that, relative to the null ($BF_{10} = 1.00$), the model including only price was 7.68 times more likely ($BF_{10} = 7.68$) while all other models, including incentive type, were less likely (BF_{10}'s ≤ 0.77). As an *addendum*, the BF of 0.06 comparing the interaction model and the two main effects model indicates that the interactive effect did not receive support from the data. The Kruskal-Wallis tests likewise revealed a statistically significant finding for price ($\chi^2(2, n=484)$ 20.606, p =< .001) but not incentive type (p = .797).

Table 4. Study 3 Means, SE, ANOVA and Bayes Factor for hours of energy shared by price and incentive type.

			Main Effects			Price x Incentive Type		
Overall Price	**Mean (SE)**	**95% CI**	**F**	**p**	**BF[a]**	**F**	**p**	**BF[a]**
free (donate) (n=163)	65.61 (3.64)	58.46, 72.76	6.187	0.002**	7.68	0.322	0.7	0.06
1/10th of what was paid (n=160)	56.81 (3.67)	49.60, 64.03						
twice what was paid (n=161)	75.05 (3.66)	67.86, 82.25						
Overall Incentive Type								
Give (n=243)	66.34 (2.99)	60.46, 72.22	0.059	0.808	0.10			
Sell (n=241)	65.31 (2.98)	59.46, 71.17						

*p < .05; **p < 0.01; ***p < .001

[a] Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0.

Post hoc Tukey tests revealed a statistically significant mean difference between twice paid (M 75.05, SE 3.66) and 1/10th paid (M 56.81, SE 3.67) conditions only (p = .001). The *post hoc* BF agreed, providing very strong evidence (BF = 49.80). While the Tukey tests for free vs. 1/10th paid and free vs. twice paid were not statistically significant (p's ≥ 0.161), the respective BFs provided inconclusive evidence (BFs: 0.45, 0.65). Thus, a larger sample is recommended to clarify this finding.

To summarise, there was no price by incentive type interaction suggesting a similar pattern of responding across groups. Hence, responses were driven by price, independent of 'giving' or 'selling'. Framing therefore appeared not to be important in explaining sharing behaviour.

For Study 3b, the one-way ANOVA indicated a statistically significant effect for available energy (F(2,483) 37.506, p < .001, η_P^2 = 0.135). Congruently, the Bayesian one-way ANOVA revealed extremely strong evidence for a difference between groups (BF > 100). The Kruskal-Wallis test (χ^2(2, n=484) 71.904, p =< .001) agreed with these results. The *post hoc* Tukey and Bayesian tests indicated a clear difference between the hours of energy shared between the 1 day

(M 11.18, SE 0.70) vs. 3 day (M 18.62, SE 0.64) sub-groups and the 1 day vs. 5 day (M 18.19, SE 0.70) sub-groups (p's < .001). The 3 day vs. 5 day sub-groups were statistically comparable (p = .897) and Bayesian evidence supported the null (BF = 0.14). Thus, individuals were willing to share a considerable amount of energy (~15.16% to 46.58%), on average, with the hospital even when resources were very scarce. When comparing the three sub-groups, regarding proportion of energy shared, the significant Pearson chi square ($\chi^2(1, n=484)$ 79.07, p < .001) and Bayesian analysis (BF > 100) indicates that as energy availability increased so did the proportion of participants willing to share the maximum of one day's energy: 23.1% (1 day) < 66.5% (3 days) < 65.6% (5 days).

To summarise, as in Study 1, the more available energy participants had, the more they shared as demonstrated by both the amount shared and the proportion of participants willing to share to the maximum amount.

The results for the price by incentive type pooled analysis, combining Study 1 (free, twice paid), Study 2 (1/10th paid) and Study 3 (free, 1/10th paid, twice paid), are presented in Table 5. The factorial ANOVA revealed a statistically significant main effect for price (F(2,819) 8.449, p < .001, η^2_P = 0.020), while the main effect for incentive type and the interaction between the two were not statistically significant (p's ≥ .179). Supplement 5-Table 5 includes price by incentive type and available energy by incentive type means, standard errors and 95% confidence intervals. The Bayesian ANOVA model comparison results indicated that, relative to the null (BF_{10} = 1.00), the price-only model was substantially more likely (BF_{10} > 100). The only model less likely than the null was the model including only incentive type (BF_{10} = 0.40). As an *addendum*, the BF of 0.03 comparing the interaction model and the two main effects model indicates that the interactive effect did not receive support from the data (Table 5). The Kruskal-Wallis test for price was also statistically significant (χ^2(2, n=825) 27.906, $p < .001$) while the incentive type main effect was not (χ^2(1, n=825) 3.428, $p = .064$).

Table 5. Means, SE, ANOVA and Bayes Factor results, combining all studies' data, for hours of energy shared by price and incentive type and by available energy and incentive type.

			Main Effects			Price x Incentive Type		
Overall price	**Mean (SE)**	**95% CI**	**F**	**p**	**BF[a]**	**F**	**p**	**BF[a]**
free (donate) (n=275)	65.89 (3.20)	59.62, 72.17	8.449	< .001***	> 100	0.035	0.965	0.03
1/10th of what was paid (n=280)	53.90 (3.21)	47.60, 60.19						
twice what was paid (n=270)	72.32 (3.24)	65.97, 78.66						
Overall Incentive Type								
Give (n=353)	66.53 (2.81)	56.79, 66.30	1.805	0.179	0.40			
Sell (n=472)	61.54 (2.42)	61.01, 72.04						
			Main Effects			Available Energy x Incentive Type		
Overall Available Energy	**Mean (SE)**	**95% CI**	**F**	**p**	**BF[a]**	**F**	**p**	**BF[a]**
1 day's energy avail (n=237)	10.81 (0.60)	9.63, 11.99	42.591	< .001***	> 100	0.651	0.522	0.07
3 days' energy avail (n=234)	17.41 (0.62)	16.20, 18.63						
5 days' energy avail (n=234)	17.85 (0.61)	16.66, 19.05						
Overall Incentive Type								
Give (n=484)	16.00 (0.39)	15.22, 16.77	3.303	0.07	0.47			
Sell (n=221)	14.72 (0.58)	13.57, 15.86						

*p < .05; **p < 0.01; ***p < .001

[a]Bayes Factors (BF) ≥ 3.0 supports H1; BF ≤ 0.33 supports H0; inconclusive evidence: 0.33 ≤ BF ≤ 3.0. .

Note: Combining all studies' samples resulted in a larger total N for Price because of the additional condition: 1/10th paid (n=120), who did not receive Scenario 1b.

Fig. 4 presents the *post hoc* Tukey tests for price. There was a statistically significant difference between the 1/10th paid and free sub-groups ($p = .022$) and between the 1/10th paid and the twice paid sub-groups ($p < .001$). Likewise Bayesian *post hoc* comparisons revealed strong evidence for a difference between the free and 1/10th paid sub-groups (BF = 27.27) and extremely strong evidence for a difference between the 1/10th paid and twice paid sub-groups (BF > 100). By contrast, the free vs. twice paid sub-groups were comparable ($p = .557$; BF = 0.16).

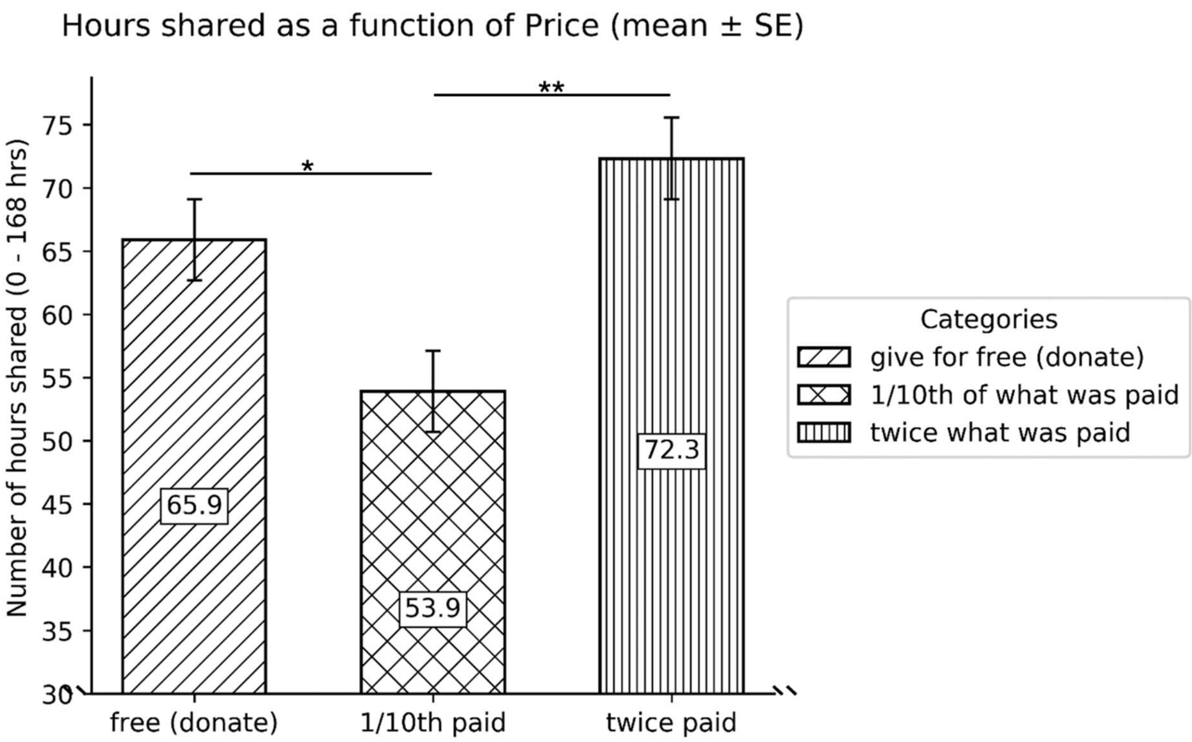

Fig. 4. Price (Studies 1, 2 & 3 combined)
Mean number of hours shared for each price condition ($1/10^{th}$ paid and twice paid are 'sell' conditions). The y-axis is truncated (30–80 hours); the break indicates the underlying scale begins at zero.
*p < 0.05; **p < 0.01

To summarise, these results confirmed Study 1's findings indicating participants' preference to either donate (free) or be incentivised (twice paid) and that conflicting the two ($1/10^{th}$ paid) negated the motivation to share.

The available energy by incentive type pooled analysis, combining Studies 1 (Scenario 1b, 'sell') and 3 (Scenario 3b, 'give') are also presented in Table 5. The factorial ANOVA revealed a statistically significant main effect for available energy ($F(2,699)$ 42.591, $p < .001$, $\eta_P^2 = 0.109$) only. The incentive type main effect and 2-way interaction were not significant (p's ≥ .070). The Bayesian ANOVA model comparison results revealed that, relative to the null model ($BF_{10} = 1.00$), the available energy-only model was substantially more likely ($BF_{10} > 100$). The only model less likely than the null was the incentive type-only model ($BF_{10} = 0.47$). Moreover, the BF of 0.07 comparing the interaction model and the two main effects model indicates that the interactive effect did not receive support from the data. The Kruskal-Wallis test indicated a statistically significant main effect for both available energy (χ^2(2, n=705) 96.556, $p < .001$) and incentive type (χ^2(1, n=705) 4.101, $p < .043$). In the latter finding's case those in the 'give' sub-set shared significantly more energy (M 16.0, SE 0.39) than those in the 'sell' sub-set (M 14.72, SE 0.58).

Following up on the significant ANOVA main effect, *post hoc* Tukey tests revealed statistically significantly differences (p's < .001) for the 1 day (M 10.81, SE 0.60) vs. 3 day (M 17.41, SE 0.62) and 1 vs. 5 day (M 17.85, SE 0.61) sub-groups. Here, the 1-day group shared the lesser amount of energy in each case. Bayesian *post hoc* tests revealed extremely strong evidence in the respective comparisons (BF's > 100). The 3-day and 5-day sub-groups shared similar amounts of energy indicated by a not statistically significant result ($p = .866$) and Bayesian evidence supported the null (BF = 0.10). The Pearson chi square (χ^2(1, n=705) 103.176, $p < .001$) and Bayesian equivalent analyses (BF > 100), as before, confirmed that the proportion of participants in each sub-group who shared 1 day's energy increased as a function of available energy: 21.9% (1 day) < 61.5% (3 days) < 63.2% (5 days).

In summary, confirming Study 1's findings, these results suggest that participants were influenced mainly by the incentive's value (price) while framing (incentive type) showed a negligible effect.

4 Discussion

This novel research examined how citizens might be anticipated to behave in a previously univestigated context: Energy scarcity arising from reliance on intermittent green energy supply sources. We used a series of between-subjects online experiments to investigate three relatively unexplored areas in the energy literature: the impact of monetary incentive relative to donations, resource (energy) scarcity and urban-rural settlement differences on the number of hours of energy shared with a local hospital during a nationwide power outage crisis. We also explored the effect of framing requests to share energy as 'give' vs. 'sell'. All samples were gender-balanced and drawn from England's urban and rural postcodes. Each study's participants were statistically comparable across demographic and sociodemographic variables and analysed using both frequentist and Bayesian statistics.

4.1 Monetary incentives and loss aversion

We demonstrated that sharing energy as a donation was comparable to sharing at zero cost and at a profit whereas sharing at a loss, whether 10% or 50%, significantly reduced sharing. This pattern accords with evidence for the 'pay enough or don't pay at all' V-shaped trend described by Gneezy and Rustichini [47] in which insufficient incentives crowd out cooperation. In our case, the 3 points of the V would be the give for free result at the top left, sell at 1/10th paid/at half paid at the lowest point and same as paid/twice paid at the top right. This suggests that warm-glow/pro-social incentives can elicit similar levels of energy sharing to reasonable monetary incentives (sell at no loss/a profit). As in Gneezy and Rustichini [47], our results highlight the critical importance of incentive design for maximal efficacy. The sharp decline among partial loss participant groups suggests a social punishment interpretation where individuals withdraw cooperation because of violation of fairness norms or expectations, a mechanism associated with negative reciprocity and motivational crowding out [48-50]. Similarly, DellaVigna and Pope [51] more recently showed that monetary incentives were more impactful than non-monetary (social comparison) incentives and that warm glow effects won out over pure altruism. In addition, we extend current knowledge by showing that incentive value outweighed linguistic framing (‘sell’ vs. ‘give’) implying that, in a crisis context, sharing was more strongly influenced by perceived economic consequences than psychological nudging. This pattern, in which substantive consequences exerts a strong influence, is broadly consistent with Kubli and colleagues’ [12] finding that prosumers’ willingness to be flexible was most strongly affected by tangible impacts like physical discomfort rather less substantive issues such as contract duration.

4.2 Energy scarcity and prosocial behaviour

Householders were willing to prioritise the energy needs of their local hospital even when their own supply was restricted. Whether available energy was extremely scarce (1 day’s energy) or relatively less scare (3 or 5 days’ energy), all participants shared a reasonable proportion of their limited resource. Those with 3 (~24%) or 5 days’ (~15%) energy shared more in absolute terms, though proportionately less relative to their total supply while those with 1 day’s supply shared proportionately more (~45%). We note that this pattern of outcomes may be partially driven by the 1-day maximum constraint. These findings suggest that in a crisis situation where the energy restriction period as well as the needs and consequences to the local hospital have been clearly presented, participants will behave pro-socially.

Various mechanisms are hypothesized to explain sharing scarce resources. These include past experience, reciprocity and maintaining positive mood [31]. Social norms and their influence on prosocial behaviour may also be important [52]. Indeed, when resources are scarce or unpredictable this could make salient a desire for fairness as a socially shared expectation to facilitate cooperative behaviour within that community (ibid). Other studies similarly indicate that people do share, but the extent of this is moderated by intra-personal factors. For instance, Roux and colleagues [26] used a series of experiments to show that while scarcity cues activated a competitive mindset motivating us to prioritise our own welfare, our inherent pro-social vs. pro-self-orientation moderates such effects. Furthermore, Cui and colleagues [9] found neurobiological evidence in their pro-social behaviour experiment that sharing scarce resources was positively associated with individual differences in level of cognitive empathy. In addition, Shah and colleagues demonstrated a reliance on 'trade-off thinking' based on one's own standards rather than on external cues during scarcity [25].

Recent work on energy-commons governance suggests that the exact reasons/mechanisms for sharing might be less important than the act of sharing itself. Wade and colleagues [18] used an agent-based model of energy communities to demonstrate that sharing was the most efficacious option for surplus energy allocation even when people acted in a selfish manner. By designing a system that enables and normalises sharing, rather than relying exclusively on market exchange, a better collective outcome (e.g. greater local use of electricity) is possible. Thus, in the context of scarcity, systems where energy is perceived and used as a shared resource would offer much value.

4.3 Settlement type and community identity

Urban vs. rural settlement types did not significantly influence sharing behaviour in any study. Similarly, in England, 65% of rural inhabitants and 62% of urban inhabitants reported giving to charity in the past 4 weeks in a survey [33]. In a study measuring demand flexibility, Roth et al. [53] found that urban and rural German households were, overall, comparable. Albeit, rural prosumer households were more flexible than urban prosumer households. Bradley [34] noted that urban vs. rural areas per se may be less important than social drivers and the like. Similarly, Kacperski and colleagues' [54] experiment showed that regional framing produced more engagement than social identity or peer-group framing. In addition, Herzenstein and Posavac's [55] charitable donations experiment showed that when participants perceived their financial resources as scarce, they gave more to local charities. We speculate, therefore, that in a crisis context where essential services are local, shared community identity and perceived collective vulnerability may be more compelling drivers of sharing than simply settlement type.

4.4 Contributions to Research

We extend current knowledge, in particular, how households respond during an energy crisis in the following ways:

First, our study provides the first experiment-based comparison of donation vs. a range of monetary incentives for energy sharing during a crisis. This work builds on existing findings under normal energy use conditions. Our results indicate a v-shaped response-pattern where donation, zero-cost and profit yield similar sharing behaviour while sharing at a loss substantially undermines willingness to share.

Second, we add clarity by showing that energy scarcity did not negate prosocial behaviour, as participants shared a considerable proportion of their limited energy even when extremely scarce. Thus, our results do not support the view that scarcity automatically elicits competitiveness or hoarding.

Third, we add to currently limited evidence by showing that urban-rural differences have a negligible influence on energy sharing in a crisis. Our scenarios focused on a local essential service and, by implication, the local community. Thus, our results support the view that community identity and collective need may be more compelling than broad geographical characteristics.

Fourth, we showed across individual studies and pooled analyses that different framing (‘give’ vs. ‘sell’) had a negligible influence on energy shared relative to the substantive value of the monetary incentives. This refines current behavioural research evidence, showing that when the consequences for both householders and community services are potentially severe, monetary value was more compelling than how the request was worded.

In sum, our work adds to behavioural and energy research by demonstrating that householders are motivated not only by monetary incentives but also by community needs and fairness, even under extremely scarce conditions. Consequently, incentive design is critical to determining cooperative energy behaviour during crises. Our results offer a behavioural foundation from which to model equitable, socially acceptable systems for emergency energy redistribution in a future energy system entirely reliant on renewables.

4.5 Policy implications

Our findings indicate that householders would be receptive to taking an active role in local energy governance during shortages. Indeed, our findings regarding available energy suggest that householders would act collectively to protect their local community’s essential services’ energy needs. This is complimented by the finding that participants willingly donated energy despite their own restricted supply. Thus, energy can be perceived as a community resource, not just a consumer product. UK government strategies, such as Net Zero, could therefore be enhanced by incorporating a mechanism for voluntary, community-driven energy sharing. Such a mechanism should include safeguards to ensure fairness to prevent householders from being pressured into sharing beyond their economic means and avoid free-riding. Our finding that responses among urban and rural participants were comparable suggests that the needs of local essential services may be a more important driver of collective action. The UK government may therefore benefit more from focusing on location-based strategies, which would rely on local households acting collectively during an energy crisis.

4.6 Limitations

There are some caveats regarding our findings. Generalisability may be limited because our samples were drawn from specific rural and urban locations exclusively within England but outside of London. In addition, we excluded adults > 65 years and non-drivers. We further note that participants were self-selected and our studies were based on hypothetical scenarios. In Study 1, one price condition was worded as 'give' because one cannot sell something for free. We therefore added a 5th price condition, *post hoc*, to clarify the results. Our 'give' vs. 'sell' framework comparison was exploratory and added *post hoc*.

5 Conclusion

In conclusion, we add to current literature by demonstrating three key points. Firstly, energy sharing was comparable whether participants donated, sold at cost or sold at a profit. By directly testing monetary incentives relative to donation, we show that the most effective strategy for a hospital in an energy crisis may be to ask residents to freely give what they can. However, if the hospital does offer compensation, covering costs is sufficient. Secondly, people were willing to share, even when their own supply was very limited, challenging assumptions that scarcity automatically triggers a self-preservation decision-making style. Thirdly, settlement type did not significantly influence sharing behaviour, suggesting that local identity or perceived community need may be more important that urban-rural differences. In addition, we showed no effect of framing (‘give’ vs. ‘sell’) suggesting that perceived economic consequences rather than wording were more impactful. Overall, our results, though provisional, offer a positive message: in a crisis, people are willing to share to help their community’s services, and would rather donate than sell at a loss. This has policy implications, highlighting the value of fair, voluntary community-centred approaches to manage future energy shortages that might arise in a green connected future society.

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