

Curbing Energy Consumption through Voluntary Quotas

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July 2023

Texas weather: Deaths mount as winter storm leaves millions without power

17 February 2021



Texas power outage



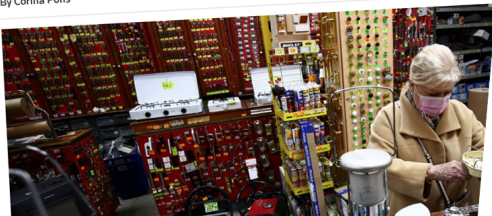
REUTERS®

Energy

November 11, 2021 12:48 PM GMT+1

Blackout fears amid energy crunch boosts gas cookers, lantern sales in Spain

By Corina Pons



European
Commission

Home > Press corner > Save Gas for a Safe Winter



Available languages: English

Press release | 20 July 2022 | Brussels

Save Energy for a Safe Winter: Commission proposes gas demand reduction plan to prepare EU for supply cuts



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News | Energy

'Unprecedented' power cuts in China hit homes, factories

Northeastern China is experiencing power cuts because of coal shortages and the tightening of emissions standards.

28 Sep 2021



Getting started

- ▶ Short-term interventions to deal with energy shortages typically involve:
 - Capping heating and cooling.
 - Cutting power at times of grid stress.
- ▶ Outages and mandatory power cuts **disrupt daily lives and businesses**, sparking public discontent.
- ▶ Some policymakers remain **reluctant to introduce rationing measures**, possibly due to concerns for their libertarian image.

Don't mention rationing: why energy crisis may need another Truss U-turn

National Grid is taking blackout risk seriously, yet PM remains reluctant to take action to limit energy usage

Fri 9 Sep 2022 14.58 BST



so far, the new prime minister has refused to either introduce mandatory rationing for households and businesses, or urge the public to cut back. The decision is deeply political.

there appears to be a deep reluctance to tell the public how many times they should use the kettle a day or when to put the dishwasher on, amid fears it would further erode the principles of libertarian Tories.

This paper

- ▶ We examine **voluntary quotas (VQs) that trade-off energy consumption for energy security.**
 - Contracts by which users willingly limit their maximum possible consumption of energy. . .
 - . . . in exchange for the guarantee that they will not suffer, or suffer as little as possible, from outages.
- ▶ Pros of VQs:
 - Not imposed without consent.
 - Allow users to sort themselves into different consumption schemes.

This paper (cont'd)

- ▶ We study VQs in the simplified framework of an incentivized online experiment.
 - Sample: 800 UK residents recruited through Prolific.
 - Captures aspects of strategic behaviour that are relevant to situations where agents face **sudden reductions in energy supply** and **do not have the time to learn how to coordinate with others**.
- ▶ Impact of VQs on energy consumption not obvious a priori:
 - A quota that restricts demand by a great extent may fail to meet its objectives because it is not appealing to users.
 - A quota that restricts demand by a small extent may be welcomed by the public but be of little help in reducing consumption.

Baseline game: setup

- ▶ A group of 10 players consume a limited shared resource of size C .
- ▶ Each player i can demand any whole amount $d_i \in [0, 20]$ of the resource.
- ▶ If the demands sum to C or less, then players receive what they demanded; **otherwise they get nothing**.
- ▶ Players choose how much they would like to consume in each of two rounds. Choices are made independently and simultaneously.
- ▶ Player i 's payoff in Round $t = 1, 2$ is therefore:

$$\pi_{i,t} = \begin{cases} d_{i,t} & \text{if } \sum_{j=1}^{10} d_{j,t} \leq C_t \\ 0 & \text{otherwise} \end{cases}$$

Baseline game: setup (cont'd)

- ▶ In Round 1 the pool size is 100:

$$C_1 = 100$$

- ▶ In Round 2, there is a 50% probability that the pool size remains 100 and a 50% probability that it drops to 50:

$$C_2 = \begin{cases} 100 & \text{with probability } 1/2 \\ 50 & \text{with probability } 1/2 \end{cases}$$

- ▶ This information is given to each subject at the beginning of Round 1. At the beginning of Round 2, players are then informed about the actual realized pool size (i.e. either 50 or 100).

Baseline game: framing



You are a tailor making shirts.

You use an electric sewing machine, the energy consumption of which is measured in 'Energy Units'. To produce one shirt you must use 1 Energy Unit. The more Energy Units you use, the more shirts you produce.

Your machine is powered by an electric generator, and so are the machines of nine other tailors. Each tailor's machine consumes 1 Energy Unit per shirt, just like yours.

You must decide how many shirts to produce, on the basis of the generator's capacity. You will make this decision twice, once in Round 1 and once in Round 2.

Baseline game: framing (cont'd)

In each round, **you can use 0 to 20 Energy Units** and produce up to 20 shirts.

In Round 1, the generator's capacity is 100 Energy Units.

In Round 2, there is a 50% probability that the capacity will remain steady at 100 Energy Units, and a 50% probability that it will decrease to 50 Energy Units due to an **energy shortage**.

The nine participants you are matched with will be faced with the same decisions as yourself. If in a decision round the overall number of Energy Units used by the 10 of you exceeds generator capacity, then there will be a **power outage**, in which case you will produce nothing in that round.

Enter voluntary quotas

- ▶ Before making their first demand decision, each player is offered the choice to either **accept** or **reject** a consumption quota.
- ▶ If the quota is rejected, then the set of possible demands and the payoff function are as described earlier.
- ▶ To accept the quota means to reduce maximum demand to $\underline{d} < 20$ in exchange for the guarantee that demand will be met.
- ▶ Player i 's demand:
$$d_{i,t} \in \begin{cases} [0, \underline{d}] & \text{if } \text{accept} \\ [0, 20] & \text{if } \text{reject} \end{cases}$$
- ▶ Player i 's payoff:
$$\pi_{i,t} = \begin{cases} d_{i,t} & \text{if } \text{accept} \text{ or } \sum_{j=1}^n d_{j,t} \leq C_t \\ 0 & \text{otherwise} \end{cases}$$

Treatments

► Treatment F (Fixed quota)

Maximum possible demand = 5 per round:

$$\underline{d}^F = 5$$

► Treatment HP (High Proportional quota)

Maximum possible demand = 10 percent of capacity:

$$\underline{d}^{HP} = 10 \times \mathbb{1}_{C=100} + 5 \times \mathbb{1}_{C=50}$$

► Treatment LP (Low Proportional quota)

Maximum possible demand = 6 percent of capacity:

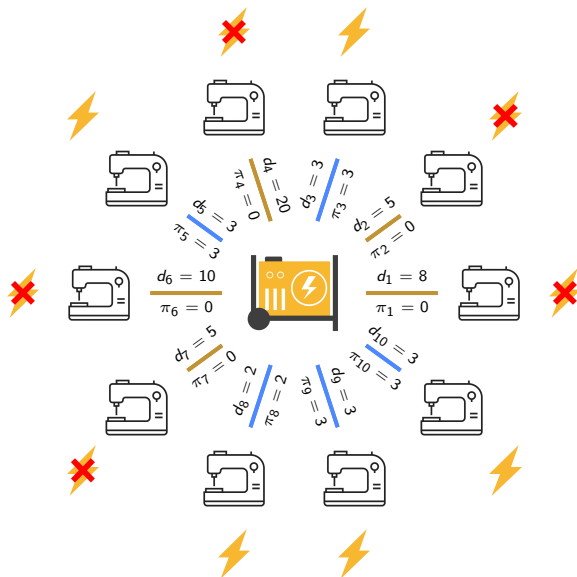
$$\underline{d}^{LP} = 6 \times \mathbb{1}_{C=100} + 3 \times \mathbb{1}_{C=50}$$

Maximum possible demand by treatment and capacity

	Baseline	Treatment F		Treatment HP		Treatment LP	
		Quota accepted	Quota rejected	Quota accepted	Quota rejected	Quota accepted	Quota rejected
$C = 100$	20	5	20	10	20	6	20
$C = 50$	20	5	20	5	20	3	20

- 4×2 design to assess and compare. . .
- The effects of a high and a low quota (**HP** vs. **LP**).
 - The effects of a fixed quota and a quota that varies with capacity (**F** vs. **LP**).

Example: Treatment LP, $C = 50$, capacity exceeded



Blue line:
quota accepted

Brown line:
quota rejected

Quota acceptance rate:
50%

Group demand:
62/50

Outage:
yes

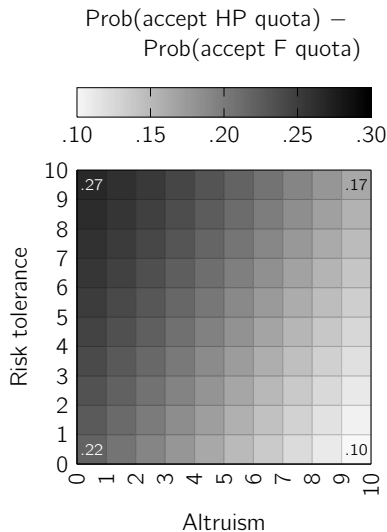
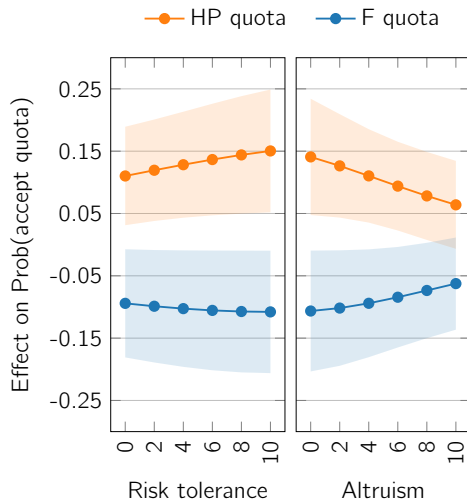
Group payoff:
14/50

Quota acceptance rates

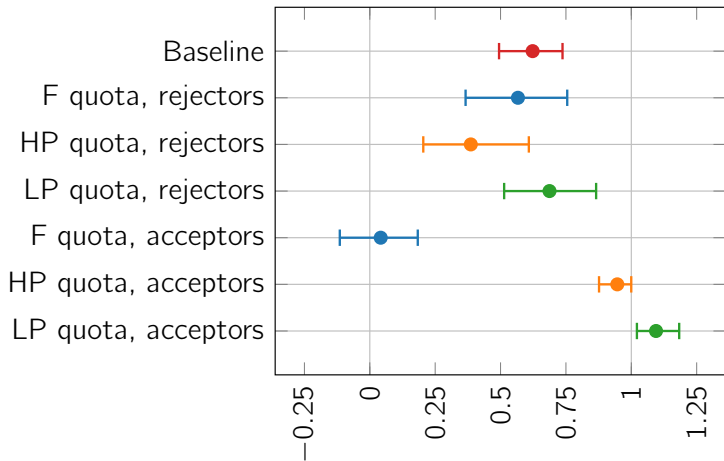
Treatment F	Treatment HP	Treatment LP
53%	77%	64%

- ▶ The probability of accepting a quota decreases with risk tolerance and increases with altruism.
 - **Intuition**: the decision to take the quota leaves more energy for others to use, and may therefore be intended as an altruistic act.
- ▶ Climate change skeptics are significantly less likely than others to accept quotas.
- ▶ Subjects in Treatments F and HP are 10 percent less likely and 13 percent more likely to accept the quota than subjects in Treatment LP, respectively.

Acceptance predictions

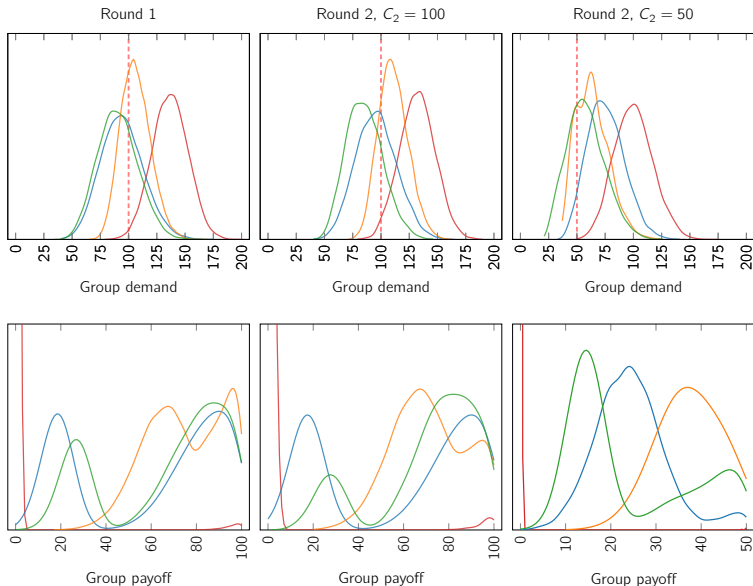


Elasticity of demand wrt capacity

































Group outcomes: kernel density estimates

Baseline · F quota · HP quota · LP quota



Group outcomes: summary of results

	Acceptance rate	Round	Group demand	Outage rate	Group payoff
Baseline		1	136.6±15.7	98.9	1.0±9.9
		2, $C_2 = 100$	132.0±15.5	97.9	2.0±13.7
		2, $C_2 = 50$	100.1±17.2	99.4	0.1±1.2
F quota	52.9 	1	94.5±18.7 	35.8 	60.0±32.8 
		2, $C_2 = 100$	95.9±18.3 	38.7 	58.3±34.1 
		2, $C_2 = 50$	75.7±16.1 	95.3 	24.4±8.1 
HP quota	77.0 	1	106.2±13.0 	64.9 	74.7±16.8 
		2, $C_2 = 100$	111.0±12.8 	78.3 	71.7±16.1 
		2, $C_2 = 50$	63.6±14.0 	77.8 	37.6±6.7 
LP quota	64.1 	1	90.4±17.6 	27.6 	66.6±27.2 
		2, $C_2 = 100$	85.4±16.1 	17.1 	71.1±22.9 
		2, $C_2 = 50$	57.9±16.7 	64.4 	23.8±13.6 

 = best;  = second best;  = third best

Wrap-up

- ▶ People are slow to adjust their demand to sudden changes in capacity.
- ▶ Although VQs seem not to be sufficient to prevent outages entirely, they might nevertheless play a role in reducing aggregate consumption.
- ▶ The choice of what kind of quota to introduce depends on the energy provider's objective.



Thank you :-)

Questions and suggestions welcome!
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