Curbing energy consumption through voluntary quotas: experimental evidence

Nicola Campigotto, Marco Catola, Simone D'Alessandro, Pietro Guarnieri, Lorenzo Spadoni

Extended abstract

Global energy consumption has steadily increased for more than half a century, reaching its highest growth in about a decade in 2018. Although the Covid-19 pandemic has delivered a large shock to the energy sector, demand is not far from bouncing back to old levels. At the same time, moreover, a number of factors – including increasingly frequent extreme climate events and the outbreak of conflicts that made fossil fuel prices spike – have caused several countries to struggle to balance energy supply with demand. In 2021, for instance, China and Texas suffered from unprecedented power crunches that plunged millions into darkness, while in 2022 European governments urged households and firms to reduce their energy consumption over fears for gas supplies. Similar news frequently comes from poor economies and remote areas, where energy security remains a major issue.

Building on these points, scholarly attention has recently turned to strategies that allow users to sort themselves into different energy consumption schemes. These notably include interruptible electricity contracts, which provide rebates to those who accept outages. If distribution companies gave users the choice between interruptible and uninterruptible contracts, then outages would be allocated towards those users who are least affected by them. Another approach is to accommodate individual preferences by means of tradable quotas, which combine a cap on overall energy consumption with the use of market mechanisms to allocate demand. One downside of such a tradable system is that it is scarcely suitable for small consumers. Moreover, it involves substantial costs associated with creating a new market and ensuring its smooth functioning.

This paper proposes yet a different strategy to deal with energy shortages, namely voluntary quotas that trade-off consumption for security. Voluntary quotas can be introduced as 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. Unlike mandatory rationing, voluntary quotas are not imposed without consent. And unlike tradable quotas, they do not require the setting up of a new market.

We study the effects of voluntary quotas in the simplified framework of an online experiment. Eight hundred UK residents were recruited to play a Nash demand game that captures key features of electricity consumption decisions. Subjects were given a production task and decided independently how much energy to demand to carry the task out. Higher energy use resulted in more production and a higher payoff. Subjects were told that energy was supplied by a generator and that if the sum of individual demands did not exceed generator capacity, then each would get their demand satisfied. Conversely, if total demand exceeded capacity, then each subject would suffer a power outage, produce nothing, and receive a payoff of zero. Energy demands were made in two consecutive rounds. In Round 1 capacity was fixed, while in Round 2 it could either remain unchanged or decrease according to a known probability distribution due to an energy supply shortage.

The experiment tested three treatments featuring different voluntary quotas, plus an untreated baseline. Subjects who accepted the quota saw their maximum possible per-period demand reduced but were sure to get what they demanded. Conversely, subjects who did not accept the quota could demand and possibly earn more but run the risk of coming up empty-handed. The first quota varied with capacity and was

designed such that in the event of unanimous acceptance and maximum energy demand by all subjects, capacity was just exhausted both in the presence and absence of an energy supply shortage. The second quota varied with capacity too, but it entitled subjects to demand less energy and always resulted in some spare capacity. The third quota entitled subjects to demand a fixed amount of energy and could exhaust capacity only in the case of an energy shortage. These treatments allow us to investigate the impact of different quota schemes on overall energy consumption, which is not obvious a priori. For example, a quota that restricts demand by a small extent may be welcomed by the public but be of little help in curbing aggregate consumption, whereas a quota that considerably restricts demand may fail to meet its objective because it is not appealing to users.

The results suggest that although voluntary quotas do not suffice to always prevent outages, they can certainly contribute to reducing energy demand and grid stress. Depending on treatment, between 53 and 77 percent of subjects accepted the quota proposed to them. When no supply shortage occurred, quotas made aggregate demand and the frequency of outages fall by up to 35 and 82 percent relative to the baseline, respectively. In case of shortage, outage frequency decreased by a less pronounced but still clearly discernible extent (up to 35 percent less than the baseline). The choice of what kind of quota to introduce ultimately depends on the energy distributor's objective: a distributor who wants to minimize outages or is keen about reducing energy use will tend to prefer low proportional quotas, whereas a distributor who wants to keep energy use close to capacity will prefer high proportional quotas. In general, proportional quotas seem to work better than fixed quotas in terms of both attractiveness to users and consumption reduction.