Implications of Energy Sufficiency on Electricity Demand and System Costs : a Quantified Assessment

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Overview

While an increasing number of countries adopt a carbon neutrality target, the search for emission cutting solutions tends to shift from low-carbon energy technologies towards demand-side transformations, including low-energy demand lifestyles. Such lifestyles can include both energy efficiency and energy sufficiency measures. While energy efficiency revolves around technology-based solutions to cut consumption and thus emissions – though not always effective due to rebound effect – sufficiency consists in reducing one's own demand as a choice. Such a transformation thus has the potential to reduce energy demand with economic benefits as it could allow avoiding some of the low-carbon investments needed to achieve carbon neutrality. However, as it is rooted in socio-behavioral considerations, it is difficult to quantifiy the potential for the reduction in energy consumption that would result from the adoption of an energy sufficient lifestyle.

In light of these issues, this paper aims at identifying plausible changes in electricity consumption behaviors in France linked with a sufficient lifestyle, and quantifying the associated energy consumption reduction and economic benefits on the road to carbon neutrality by 2050.

Method and model

The scope of the paper is French electricity consumption by 2050. Concretely, the paper compares a Reference scenario achieving carbon neutrality by 2050 based on of the French Government Low Carbon Strategy, where no sufficiency is taken into account, with a Sufficiency scenario.

To model scenarios, the study relies on a detailed bottom-up modelling of French electricity consumption and of the European electricity system, both robusts tools used for the elaboration of French TSO RTE's yearly adequacy reports. The bottom-up modelling of electricity consumption covers all end-use sectors and includes more than 30 electricity uses, from lighting, cooking, space and water heating, household appliances and digital devices… to electric vehicles, railway and industry. Seasonal, weekly, daily, hourly demand variation are modelled for each use based on the extensive observation of historical data and past demand profiles. The bottom-up modelling of the electricity system covers extensively French power capacities and a simplified representation of European countries interconnected with France. Consumption and power generation are linked dynamically to allow demand-side flexibility.

In terms of scenario narrative, the Reference scenario was built as a carbon-neutral scenario by 2050, including major technological shift of all power generations capacities to low-carbon technologies and also major changes in end-use sectors : electrification of transport, heating, energy efficiency measures.

In order to build the Sufficiency scenario, an extensive literature review on social dynamics towards energy sufficiency was conducted, first to define energy sufficiency principles, energy sufficiency behaviors, and then to identify emerging social dynamics in current society – although quite minor today. Different scales of action were to be considered: individual action, which is the easiest to conceptualize and quantify (individual choices regarding energy consumption at home, use of transport…), collective scale, and institutional and political scale. Only sufficiency trends that already existed in today's society, even though not widely adopted, were considered as likely to develop in the Sufficiency scenario; theoretical proposals for a sufficient lifestyle that were found in literature were not considered.

Confronting all the identified actions to a close review of parameters in energy model allowed a sectoral assessment of energy consumption reduction, and then an economic assessment was conducted.

Results

The Reference scenario resulted in a 645 TWh consumption in 2050 with an entirely carbon-neutral system with annualized full costs (power generation, transmission and flexibility) between 60 to 80 billion euros per year.

For the Sufficiency scenario, energy sufficiency as a lifestyle was first defined through a transversal (cross-sectoral analysis). The description of energy sufficiency includes material sufficiency (longer lifetimes for objects, eco-conception, less appliances and equipments, waste reduction), relocating some activities (local agriculture, dense neighborhoods and '15 min cities'), more sharing (goods sharing, sharing of facilities and rooms in housing: laundry rooms etc.); slower lifestyle (stronger speed limitation on roads, reduction of car use through city planning, remote working); more concern for nature and environment (more renewables, alternative agriculture, fresher and more local food, less transformed food, less meat, city planning reducing artificialized surfaces). Existing energy sufficiency trends are however still minor, and social dynamics also show that part of the population are adopting behaviors that are opposite to sufficiency: opinion surveys show that a majority of French citizens wish for a larger house thus more floorspace, urban trends in the latest decade show a tendency contrary to dense city center; etc. The identified sufficiency trend were then quantified as energy consumption cutting measures by sector and by use.

In the residential sector, sufficiency translates into more space sharing and appliance sharing in residential buildings, which is reflected in a rise in people per household (while the actual trend is decreasing) and a certain amount of 'share housing' in new buildings. Within homes, sufficiency also translates into reducing setpoint temperature for heating by 1°C - this lever was limited to 1°C based on contradictory trends observed on the field: about two thirds of French people are ready to limit the room temperature for environmental concerns according to opinion surveys, while field surveys showed that people actually heat up to 20 or 21°C instead of the nationally recommended 19°C. For hot water, we consider a 25% reduction compared to today's average, based on the lowest levels observed today by French environmental agency ADEME. Such sufficiency measures account for a 22 TWh reduction compared to the initial level of 135 TWh in the Reference scenario.

In the tertiary sector, the most important sufficiency measure is remote working, inducing less floor area for offices and associated electricity use. Consistently with post-lockdown opinion surveys for both employees and managers, a number of 2,5 days a week for office jobs was considered. Sufficiency in the tertiary sector also means applying a voluntary limitation of energy use in offices: switching off screens and computers as much as possible. Besides, more local and direct supply for food and goods in general could reduce shop size, and energy savings come from limiting advertizing screens in public spaces. These measures reduced the tertiary demand by 18,5 TWh from a level of 113 TWh in the Reference scenario.

In the transport sector, as in the tertiary sector, sufficiency means remote working, so less short-distance trips. More relocation would mean shorter distances in urban areas ('15 min cities'). Sufficiency in the transport sector also means significant modal shift. However, calibrating a plausible modal shift is difficult: past experiences of boosting public transport infrastructure show that even over 15 years, modal shares shift by only a few points. The share of car mobility in total passenger.km today is around 80% today according to national transport survey; a sufficiency narrative implying massive modal shift in urban areas, progress of car sharing in rural areas, and report from plane to train for long-distance (national trips) would allow to reduce the car mobility share around 55 to 60% as a maximum. In particular, there would be more transport sharing for short distances, which would increase the occupation rate. Freight would be reduced by a more local supply, and sufficiency would imply a modal shift towards train. However such modal shift can be limited by the saturation of the train network and need for infrastructure. We also consider that there would be no progress in the occupation rate of freight vehicles since it should already be economically optimized. These changes account for a 22 TWh reduction from the reference level at 99 TWh.

For the industrial sector, sufficiency measures consist mostly of reflecting the impact of sufficiency measures in the other sectors: less cars or less housing surface means less production for industry. Recycling and circular economy practices can also intervene directly in the industry sector. Regarding food consumption: a sufficient lifestyle privileging less transformed food induces less production in food industry. The development of alternative agriculture practices reduces the need for nitrogen fertilizers. In link with the transport sector, the reduction of passenger transport induce a reduction in vehicles sales; the adoption of a sufficient lifestyle also means a reduction in vehicle size. Longer lifetimes for appliances and equipments reduce sales and thus demand for manufacturing industry; also, mutualisation considered in the residential sector means less appliances and a reduction in building construction. A more sufficient approach of materials in general means a higher share of biosourced construction materials, more recycling in the industry, a strong reduction of plastic demand (single-use plastics being targeted in priority), less paper and carton use for advertising and wrapping means a reduction in paper and carton production. These measures account for a 20 TWh reduction from the reference level that was 180 TWh.

As a result, total energy savings triggered by identified sufficiency levers are assessed to about 90 TWh, about 15% of the total amount for electricity consumption of the Refence scenario. Economic assessment of the investments needed to build an carbon-neutral electricity system to supply the Reference scenario and the Sufficiency scenario show that the adoption of a Sufficiency scenario could allow up to 10 billion euros per year cost reduction in annualized full system costs (power generation, transmission and flexibility).

Conclusions

This paper offers new insights on sufficiency as it proposes a refined definition of sufficiency in its application sector by sector, with each sufficiency measure rooted in a actually observed trend. While this methodology tends to limit the potential of sufficiency to cut consumption and costs, it stems from the fact that observed sufficiency trends are still minor, and that other existing trends in consumption behaviour could as well drive demand levels up. Further analysis on sufficiency could be associated with higher scale action, on urban form and infrastructure management at large.